ATLAS Performance Highlights

Davide Cieri (MPP Munich) on behalf of the ATLAS Collaboration

07. June 2021 - LHCP2021

ATLAS EXPERIMENT

MAX-PLANCK-INSTITUT FÜR PHYSIK

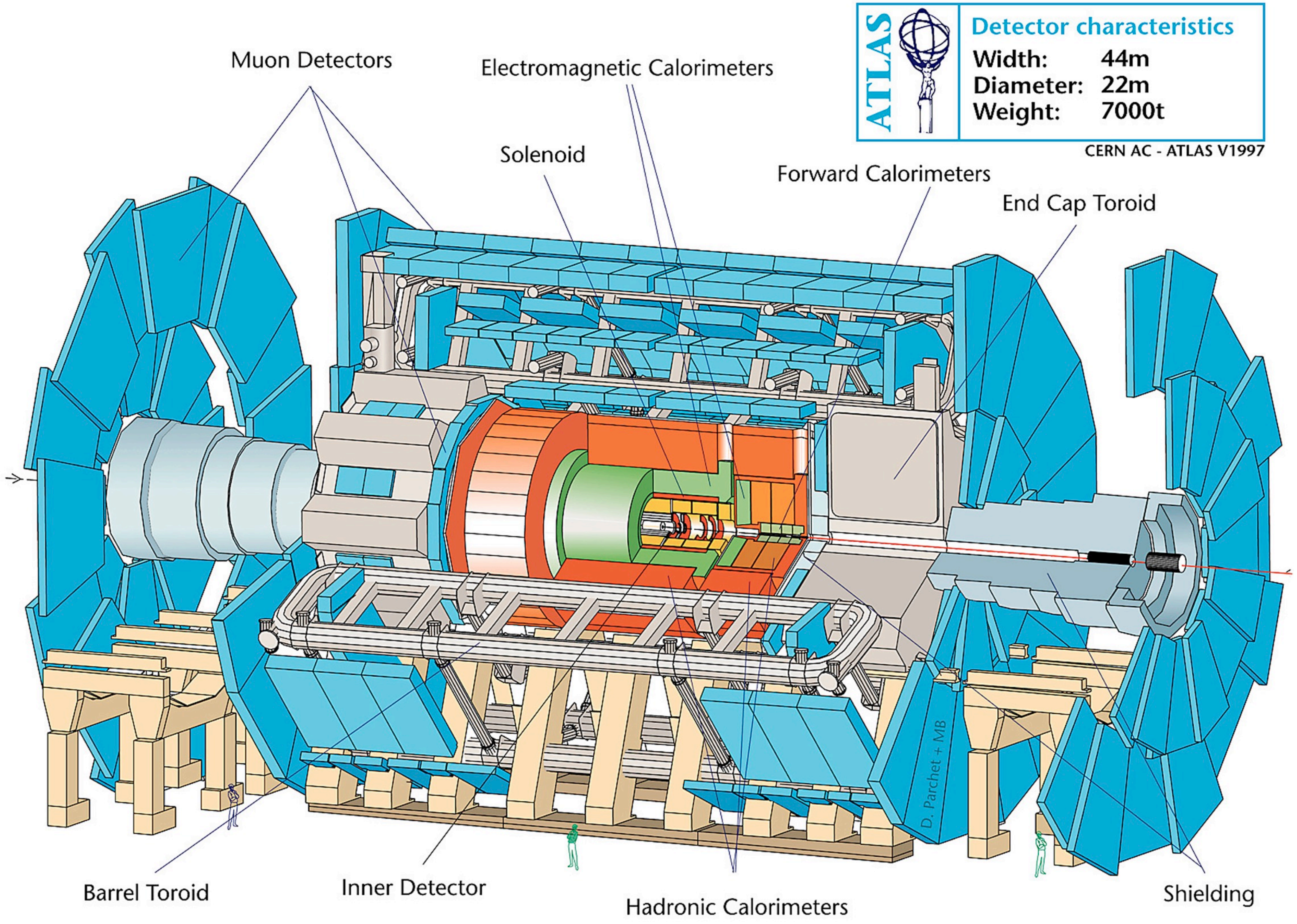
Introduction

Discussion
Zoom Room

- Highlight on performance of lepton and photons
  - Identification efficiencies/scale factors (ratio of data/MC efficiency)
  - Scale Factor used to "calibrate" simulation to match data
- New results
  - Updated muon reconstruction and identification
  - Displaced leptons reconstruction
  - Boosted di-τ reconstruction and identification
  - Merged *ee* reconstruction and identification
- Results from run II data (2015-2018)
- Tracking performance on Thursday by Mia
- Flavour-tagging / Jet / Met performance on Thursday by Jonathan

ATLAS Detector

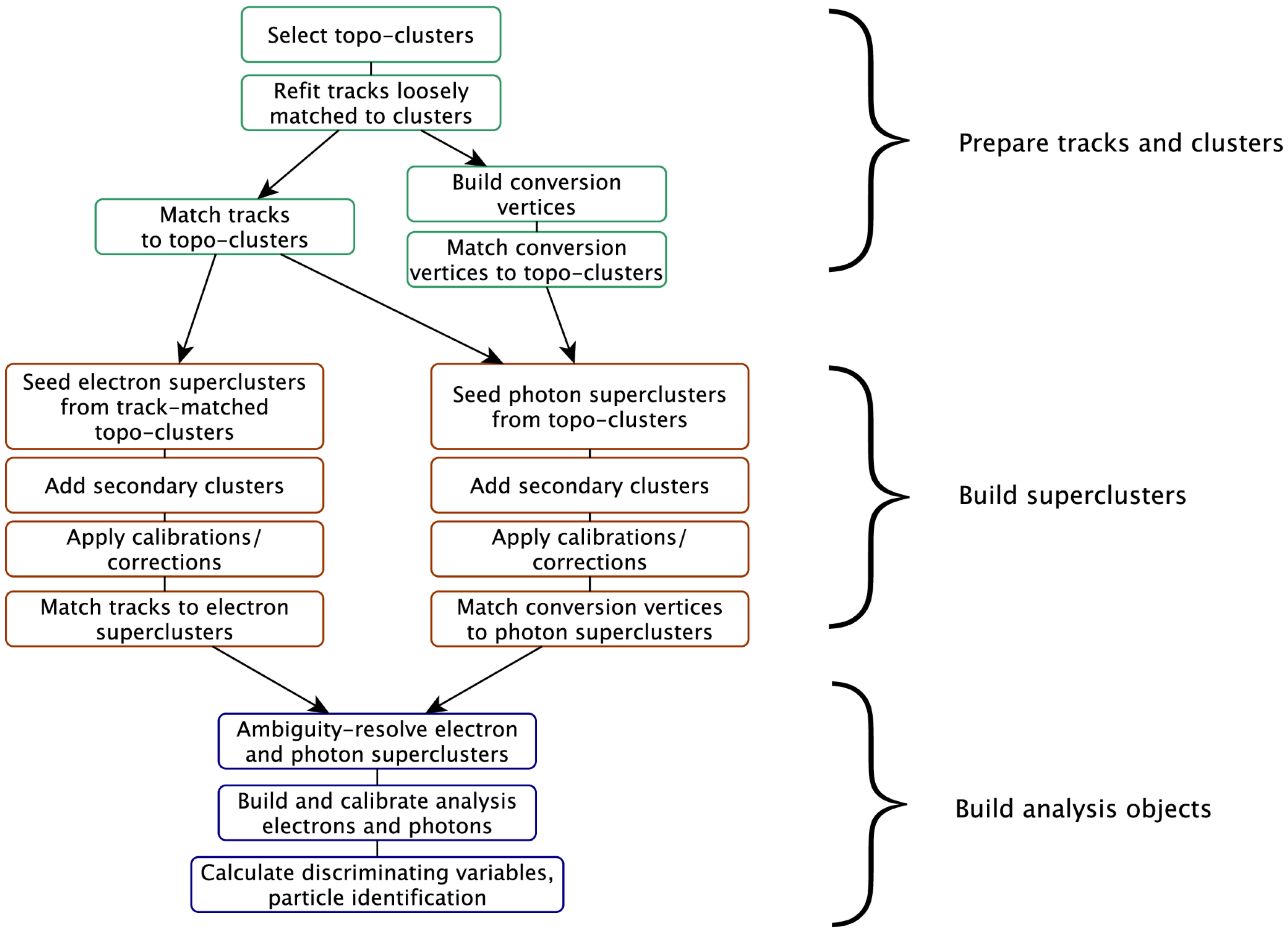
- Inner Detector, $|\eta| < 2.5$
  - Silicon pixel and microstrip (SCT) and straw tubes (TRT)
  - 2T solenoid magnetic field
- LAr Electromagnetic Calorimeter
- Scintillators and LAr for Hadronic Calorimeter
- Muon Spectrometer using trigger (RPC/TGC) and high-precision tracking chambers (MDT/CSC)
- Toroid magnetic field for Outer detector
  - ~0.5T in the endcap, ~1T in the barrel



Electron and Photon Reconstruction

JINST 14 (2019) P12006

- Reconstruction for |η|<2.5 starts from **topo-clusters** in the calorimeters
- Clusters are matched with tracks within a Region-of-Interest (RoI)
  - Converted and unconverted photons distinguished based on conversion vertex and hits in Si layer
- **Superclusters** are formed and matched to tracks
- Final calibration and analysis object creation
- Different procedure for forward electrons

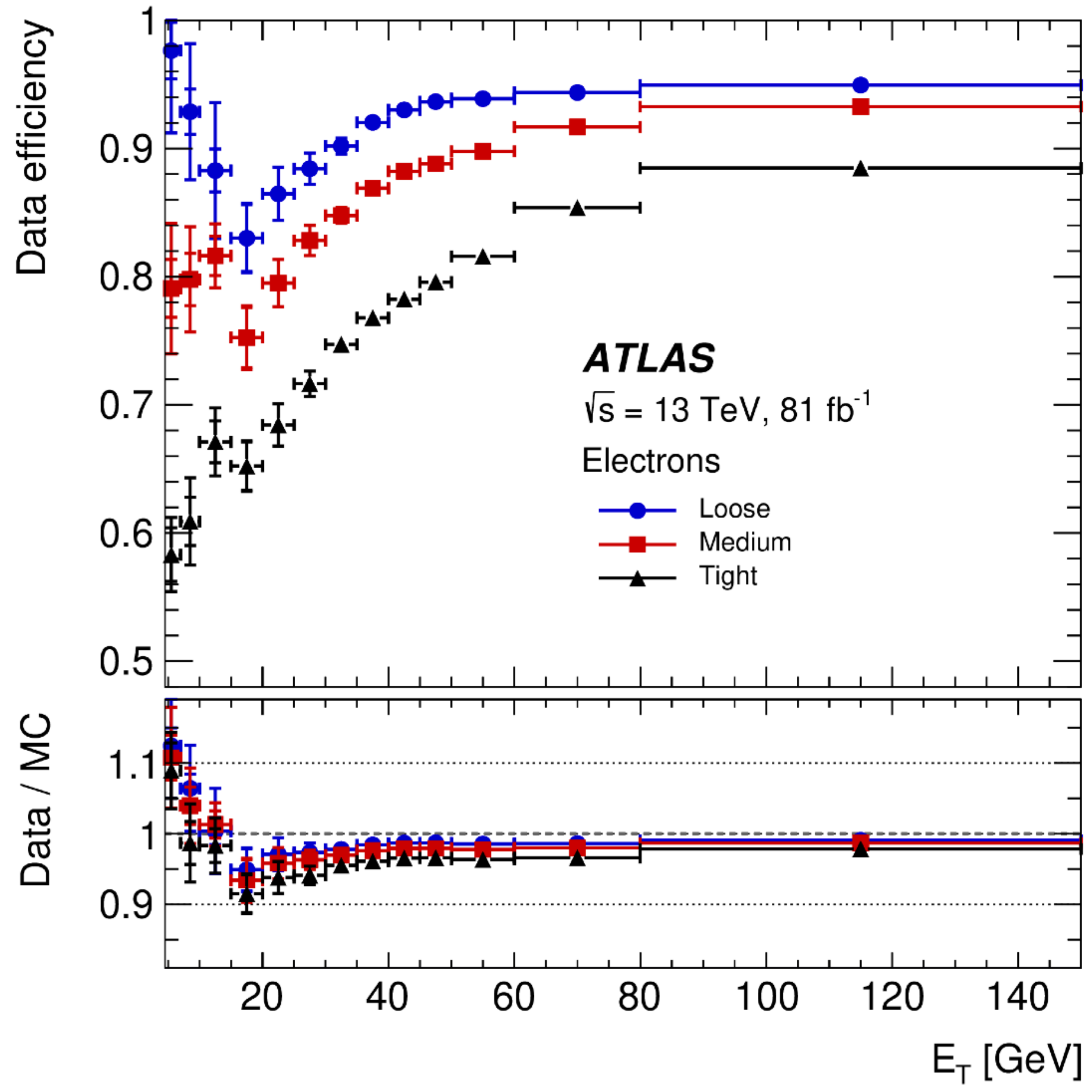


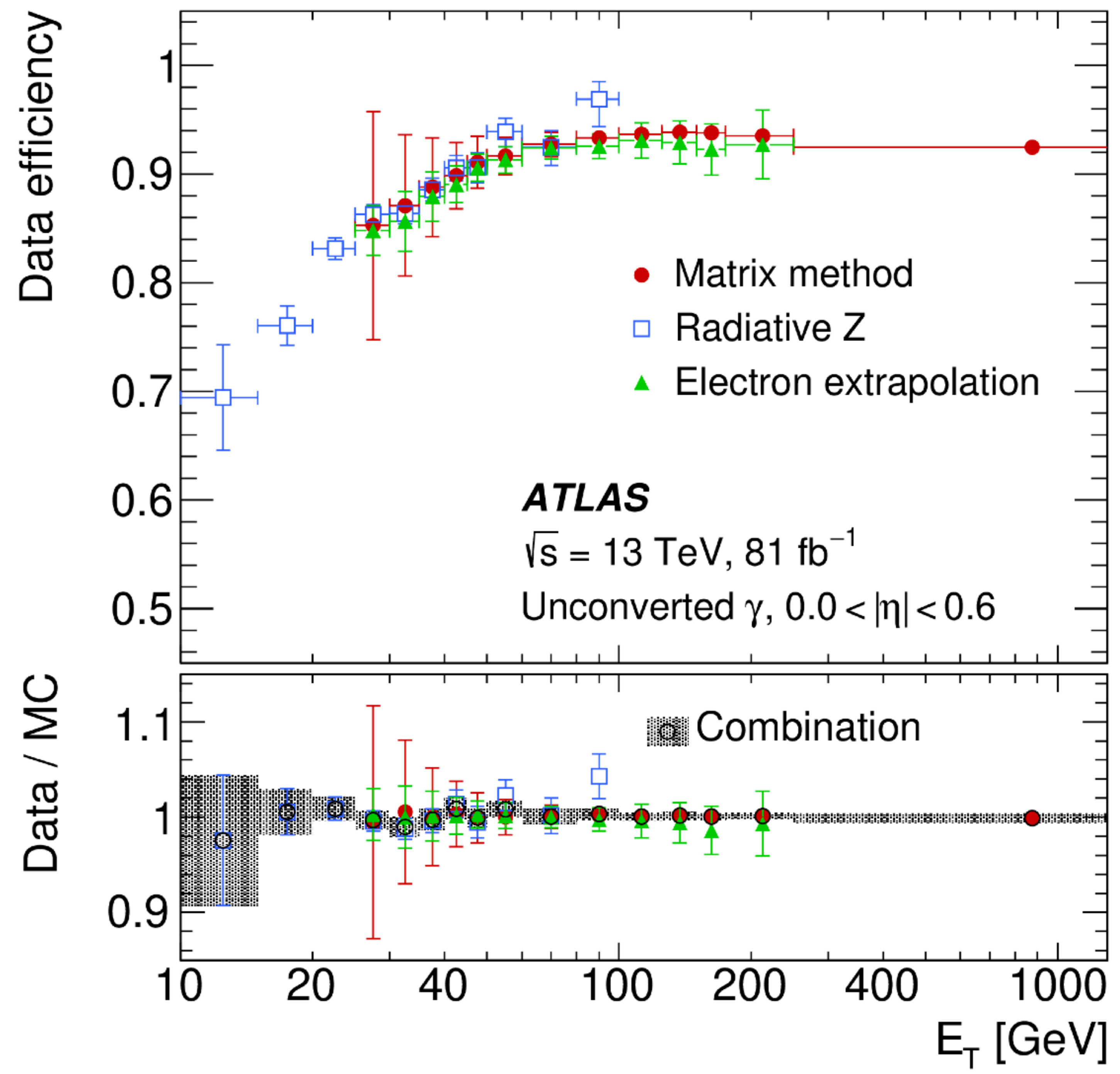
eγ Identification

JINST 14 (2019) P12006

Eur. Phys. J. C 79 (2019) 205

- Electrons Identification
  - Using information from electron track, transition radiation in TRT, lateral and longitudinal development of EM shower
  - WPs tuned using *Z—>ee* for p_T > 15 GeV and J/ψ for p_T < 15 GeV
  - Uncertainties at ±1% above 30 GeV
  - Scale Factors within 5% from unity above 20 GeV
- Photon Identification
  - Cuts on calorimetric variables (shower shapes, deposited energy in the HCAL)
  - MC shower shapes corrected with data-driven "fudge" factor
  - Efficiency calculated in three samples (Inclusive photons, *Z->llγ*, *Z->ee* events)
  - SF compatible within uncertainties
  - Delivered SFs combined using weighted average
  - Uncertainties range between 12% to 0.5%





eγ Isolation

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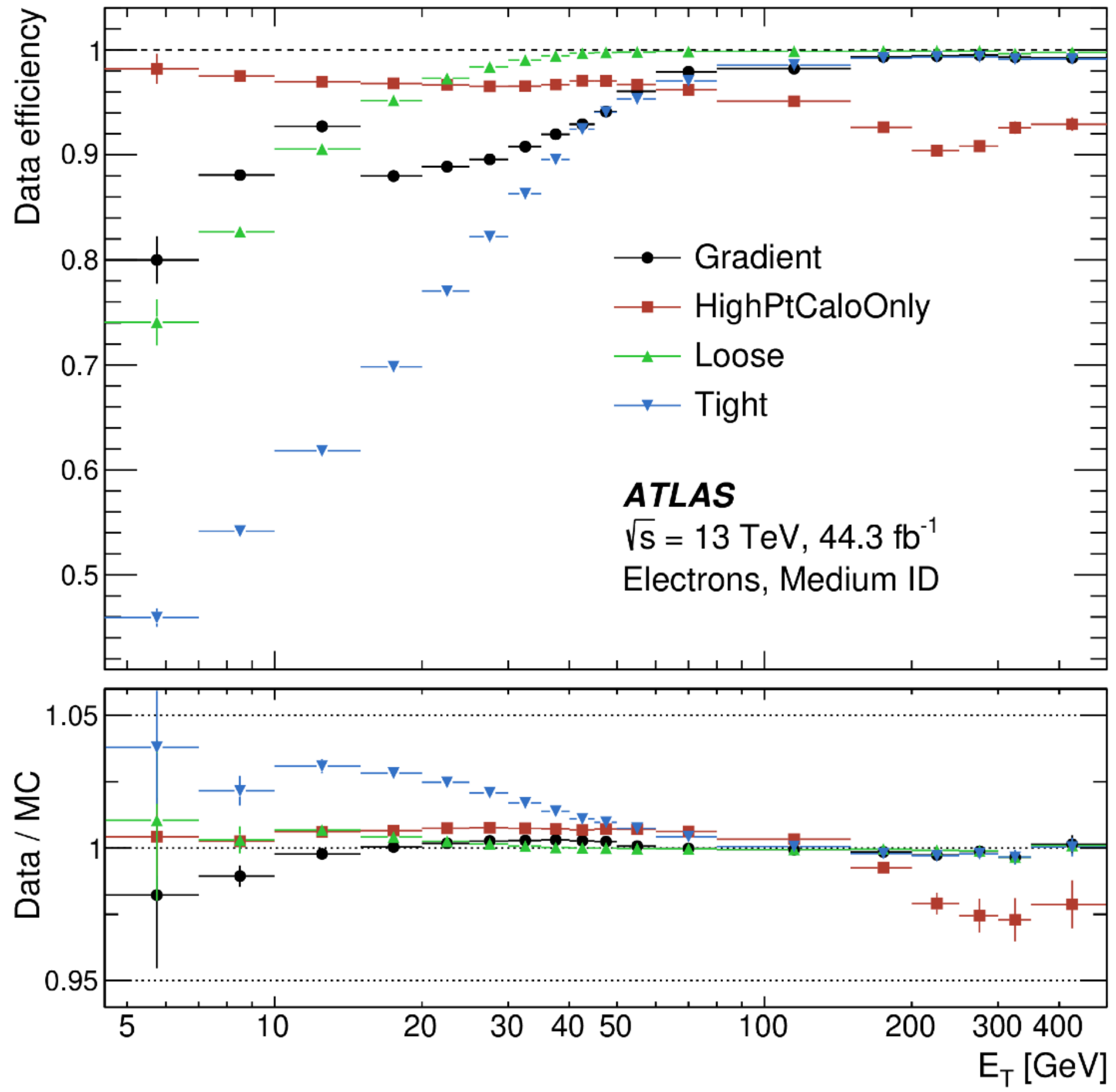
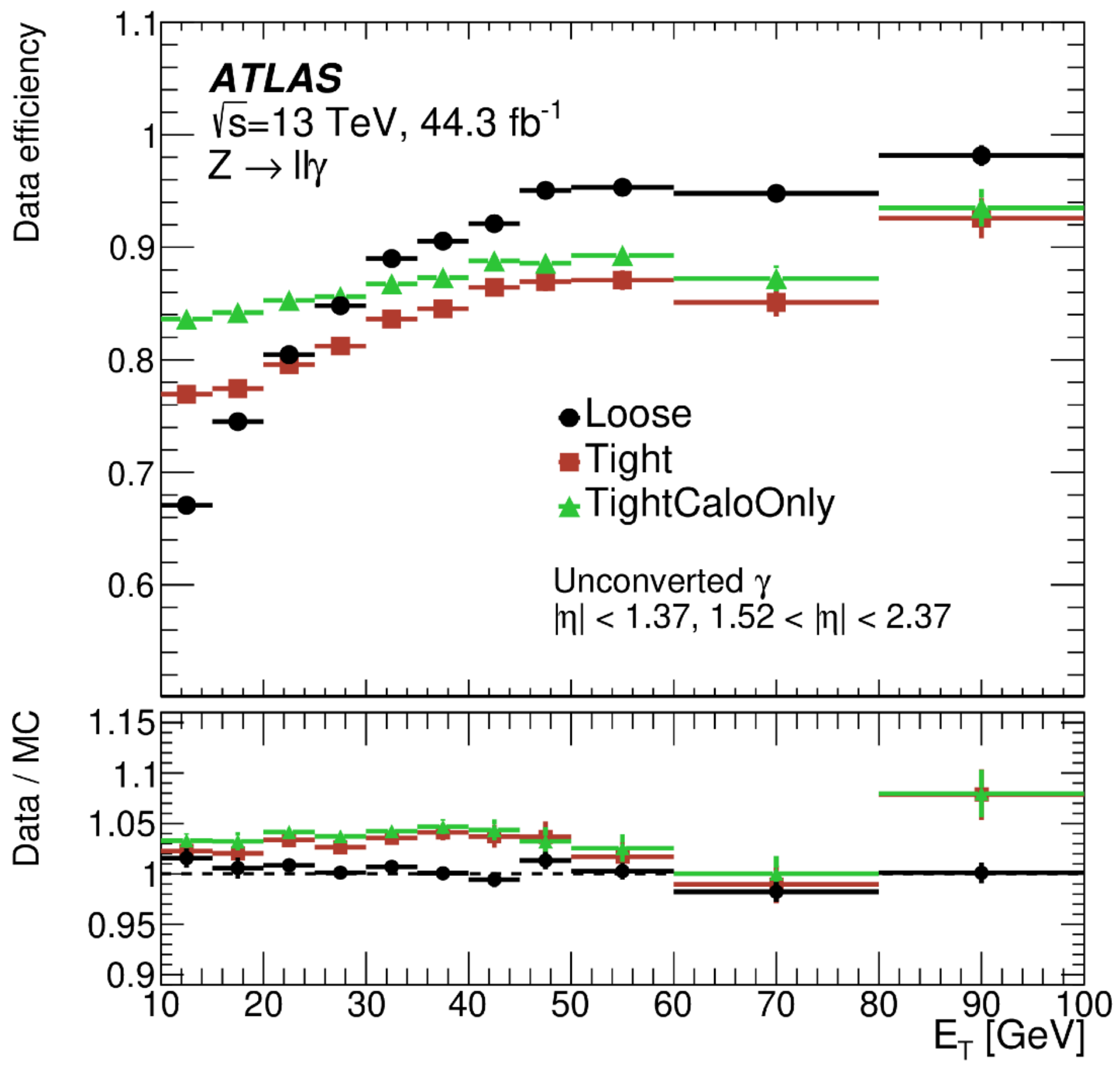
- Calorimeter isolation E_T^{Cone} computed using clusters whose barycenters lies within a cone centred around *eγ* cluster
- Track isolation cone size *ΔR* decreases as function of electron p_T
- Three WPs with fixed requirements on calorimeter and track isolations
- Overall SFs are within 5% from the unity

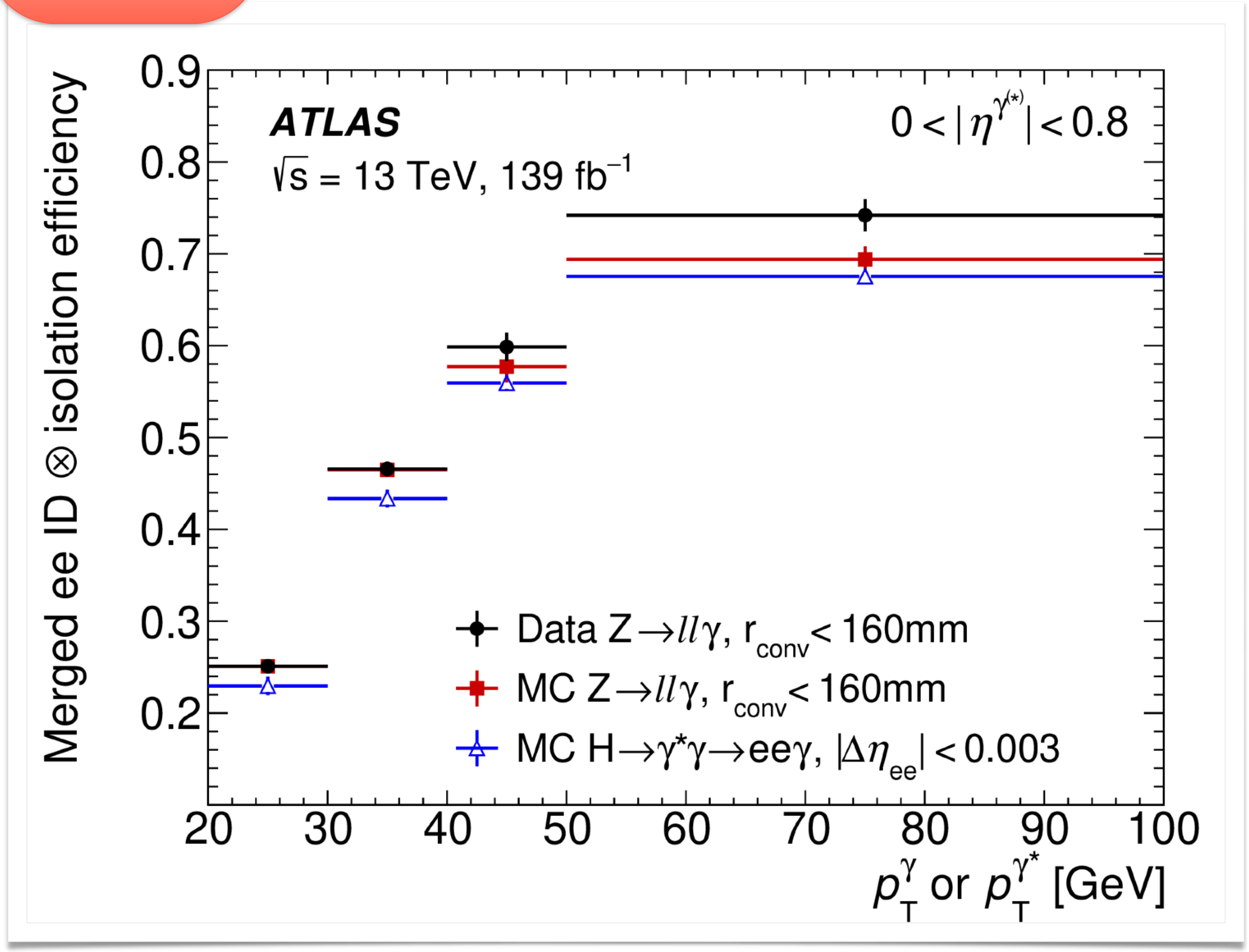




Merged-ee Identification and Isolation

arXiv:2103.10322

NEW!!

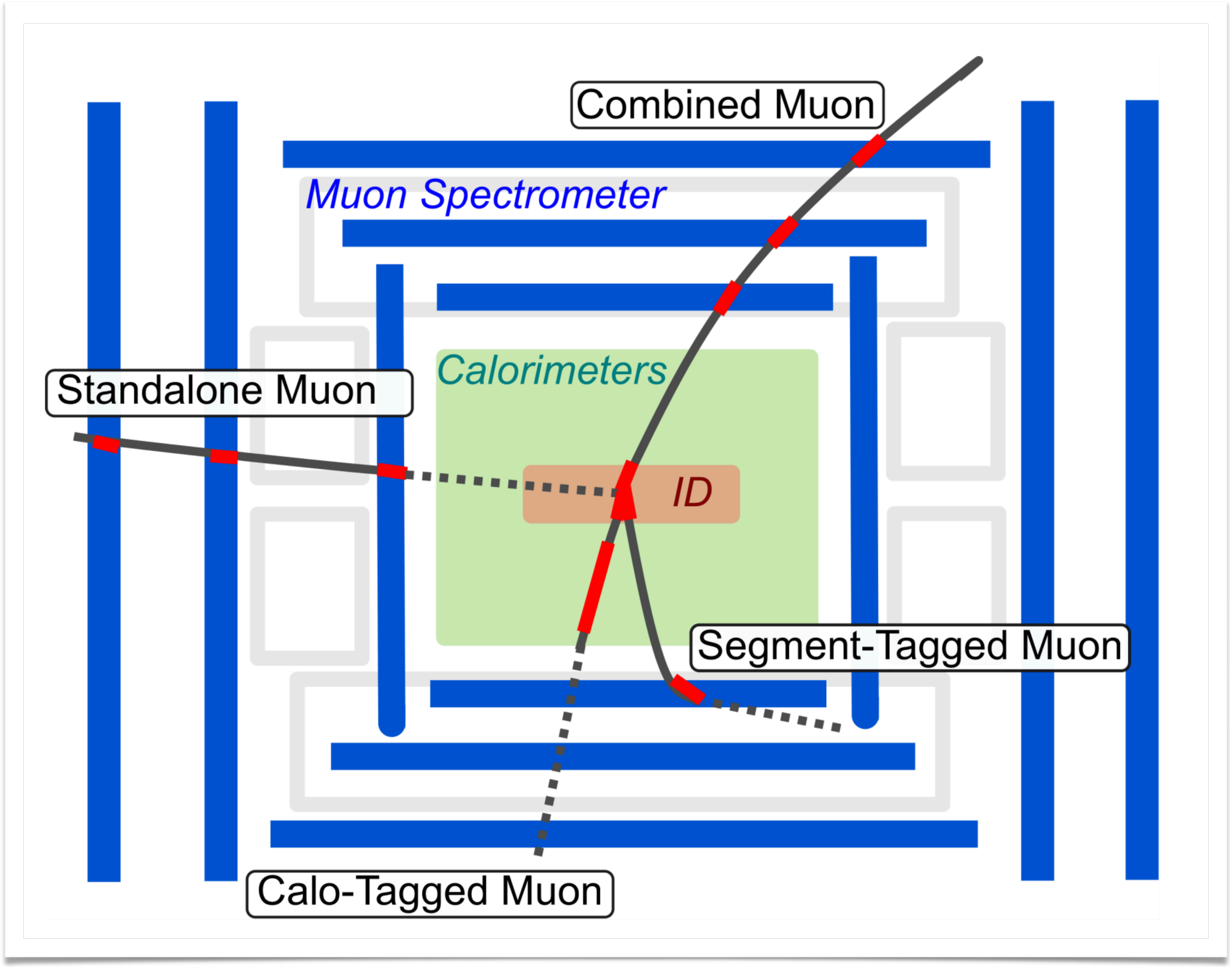


- *H->llγ* (*m_ll*<30GeV) interesting to probe BSM coupling modifications
- Merged *ee* defined as a topological cluster in the EM calorimeter associated to two opposite charged ID tracks
- Merged-*ee* energy calibrated as a converted photon with a 30 mm conversion radius
- Multivariate discriminator to separate γ* signals from jets or single electrons
- Efficiencies calculated with tag-and-probe using Z->llγ decays
- SF within 0.9 and 1.1 with uncertainties between 2% and 9%

Muon Reconstruction

arXiv:2012.00578

- Four complementary types of reconstructed muons: Combined, Segment-tagged, Stand-alone and Calorimeter-tagged muons
- Five reconstruction WPs, depending on the kinematics and desired purity
- Two methods to measure efficiency
  - Tag&Probe in the $|\eta|<2.5$ region (ID acceptance)
  - Double-ratio for $2.5<|\eta|<2.7$
- $Z \to \mu\mu$ and $J/\psi \to \mu\mu$ decays used to measure efficiency

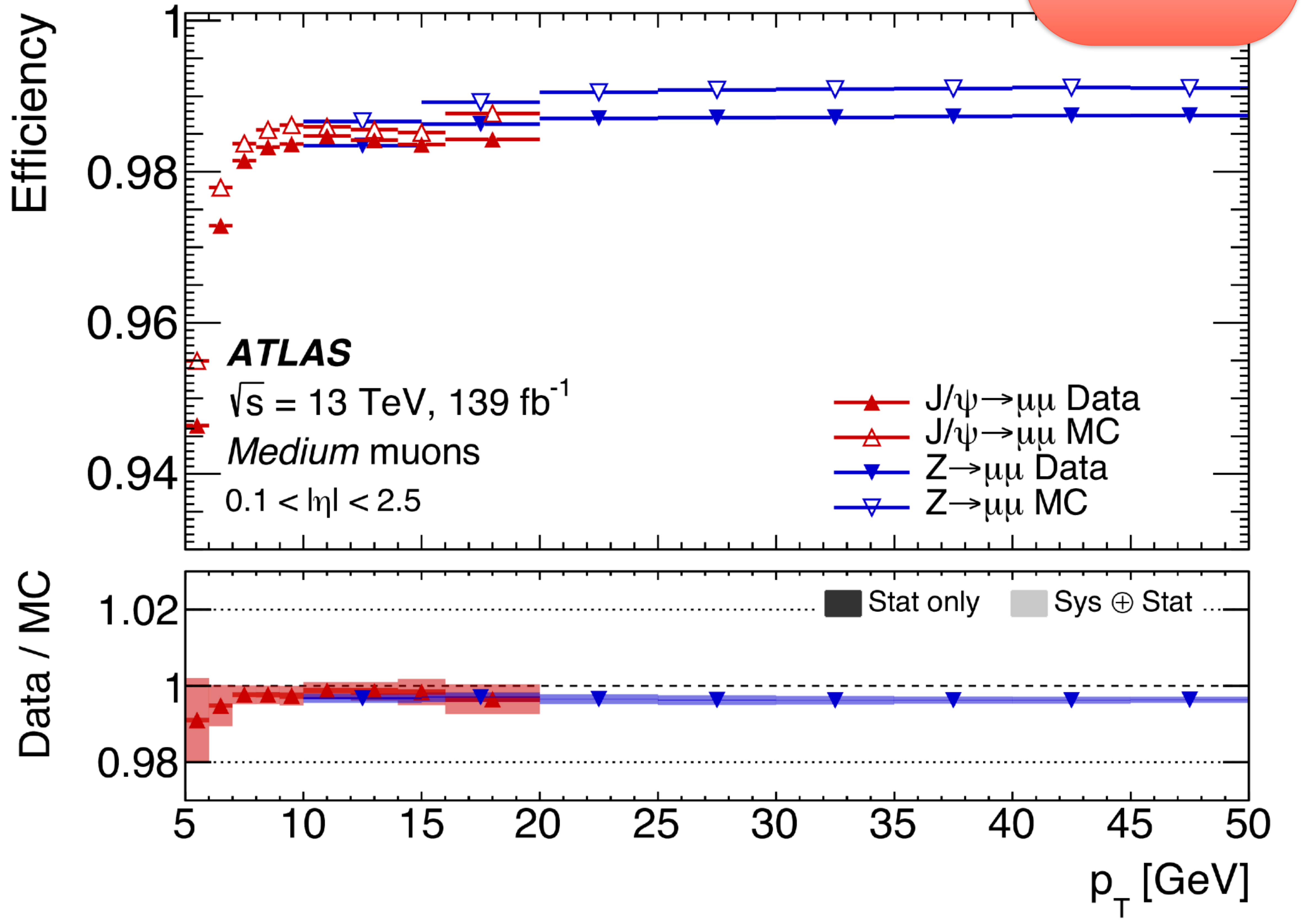


Muon Identification

arXiv:2012.00578

- Efficiencies from J/ψ and Z decays compatible in **overlap region**
  - Large uncertainties at low pT due to larger **background contamination**
- Efficiency and SF stable after 10 GeV
- For $3 < p_T < 15$ GeV, SF measured with J/ψ decays in the **(p_T, η)** plane
- For $p_T > 15$ GeV, SF measured with Z decays in **(η, Φ)** plane

NEW!!



Muon Identification

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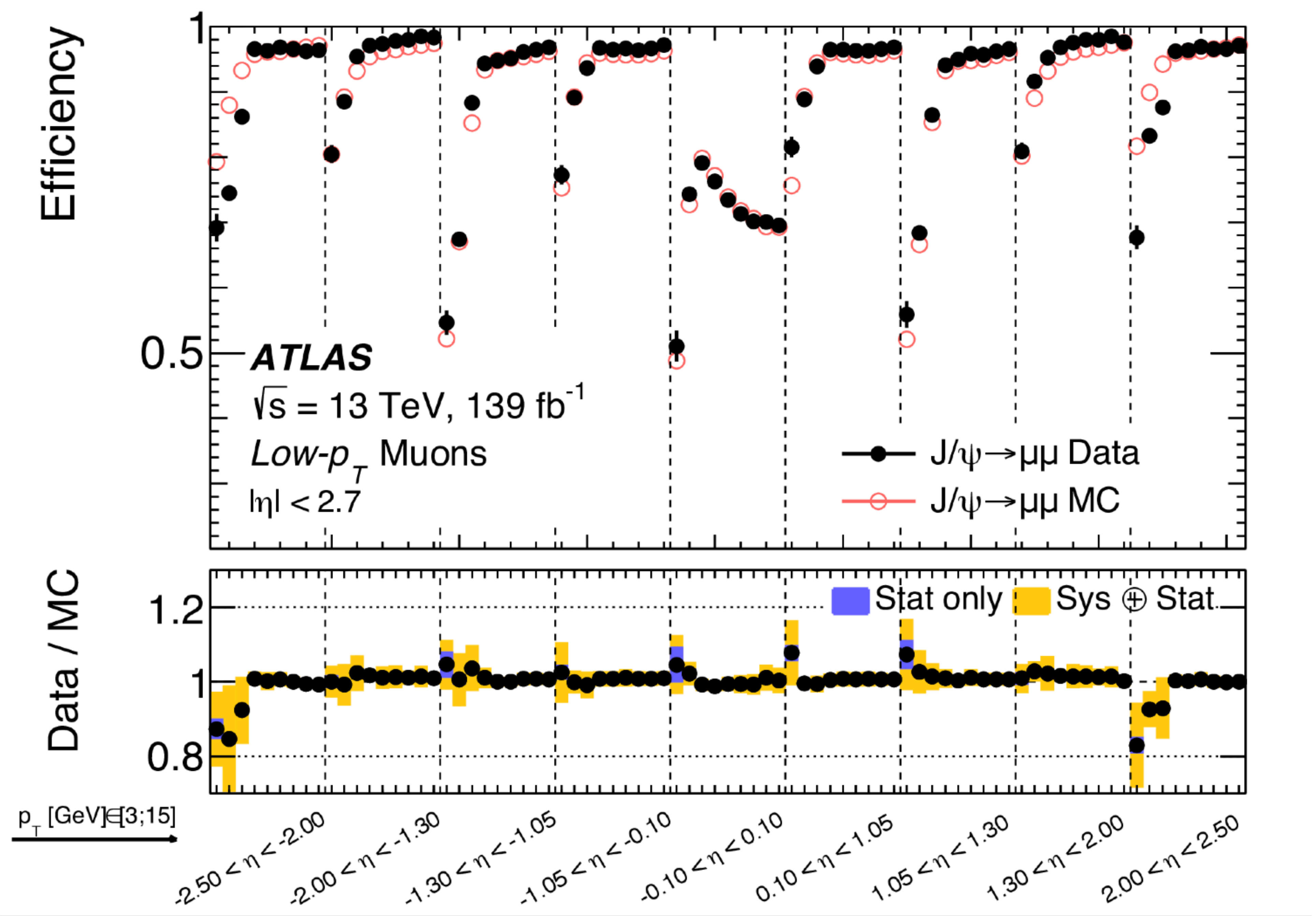
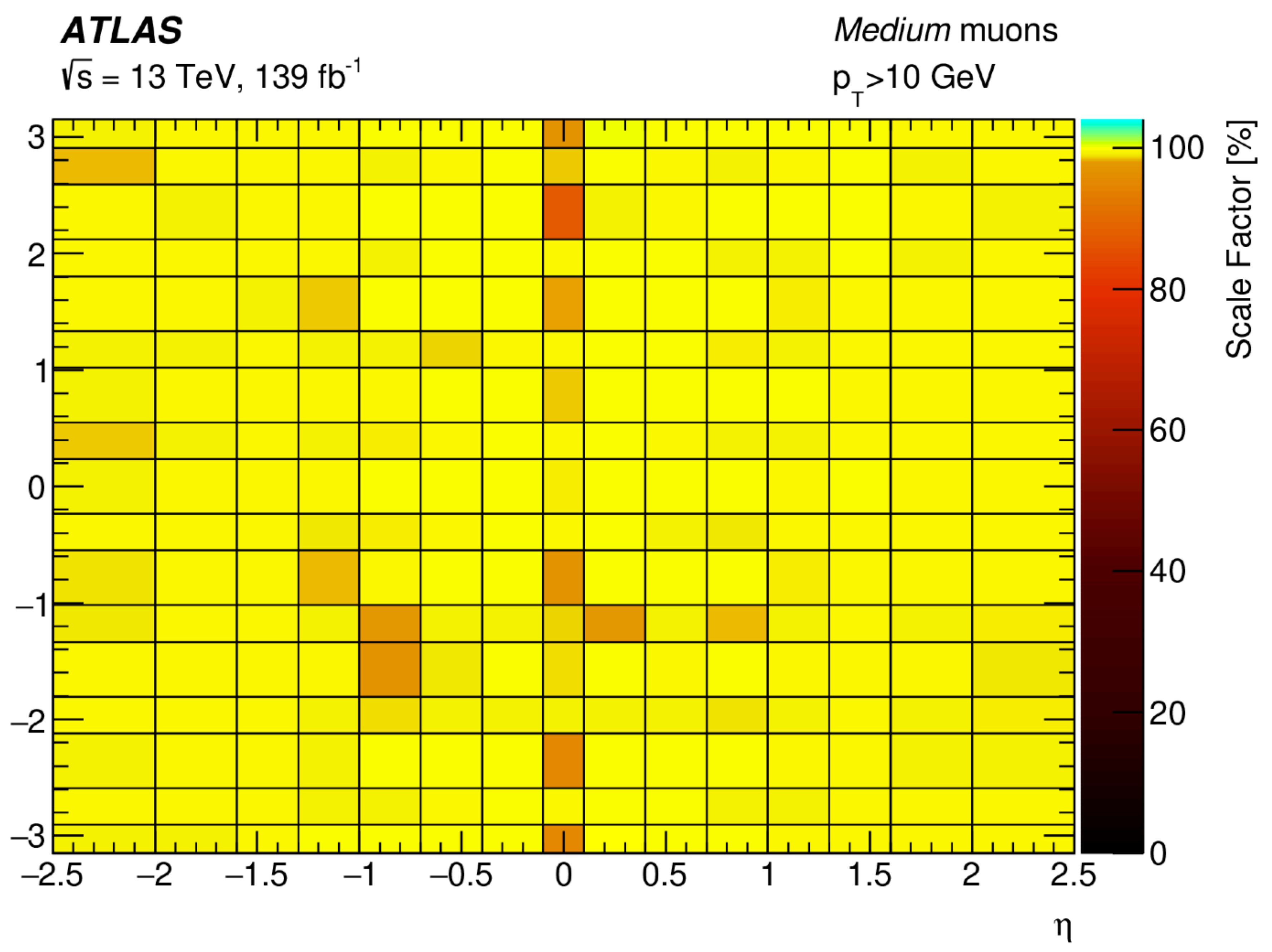
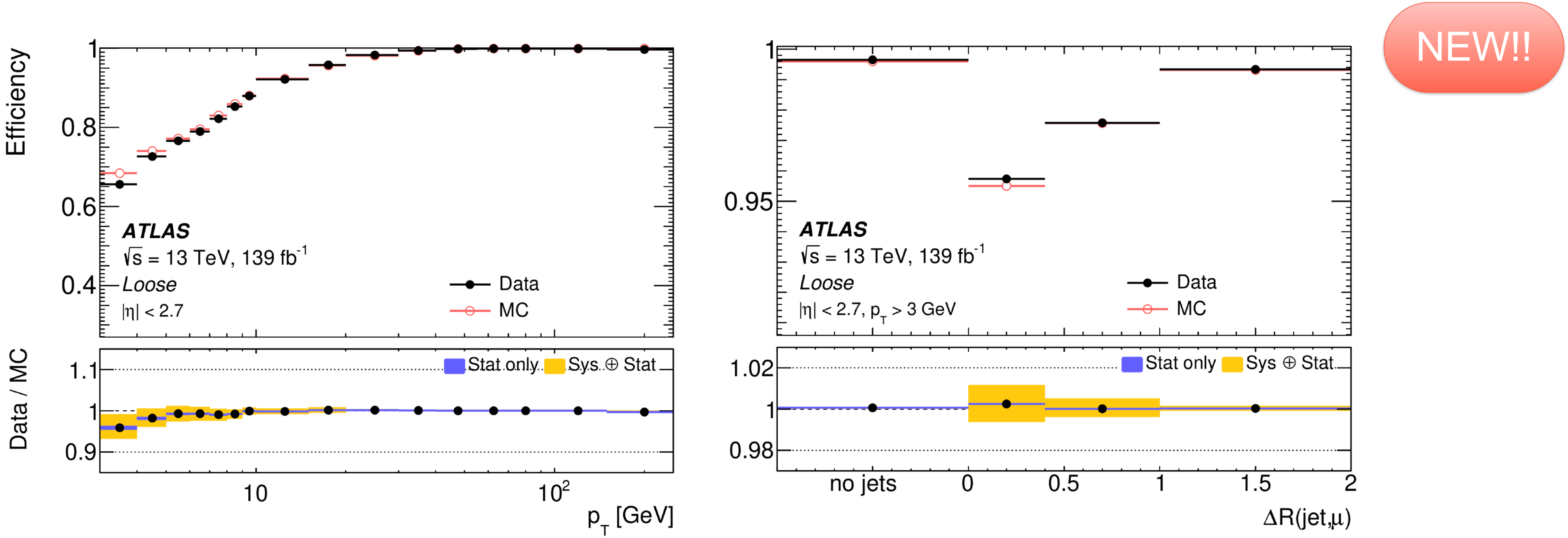




- Good agreement in Low-p_T between Data / MC, except in $|\eta|>2.0$, $p_T < 4$ GeV region
  - Faulty Cathode Strip Chambers (CSC) not modelled in simulation, lower segment-reconstruction efficiency in CSC relative to simulation for low-p_T muons
- Above 10 GeV, overall agreement at 0.5% level
  - Some inefficiencies due to detector support structures or poorly aligned chambers

Muon Isolation

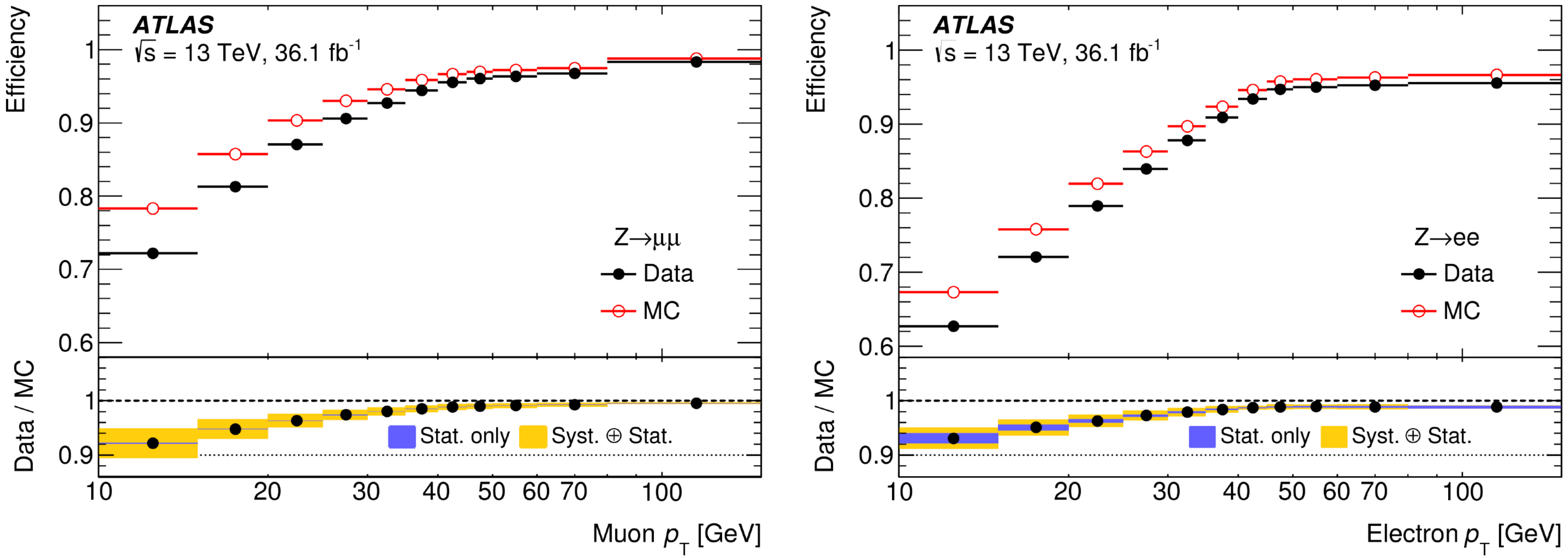
arXiv:2012.00578



- Only *Z* **decays** with $p_T > 3$ GeV probes considered
- Six working points
- SF measured as function of p_T and ΔR from the nearest hadronic jet
- Agreement at per-mille level for p_T>10 GeV.
- Increasing uncertainty at low p_T and near or close to jets, due to the MC modelling uncertainty (Pythia vs Sherpa)

Rejection of non-prompt leptons

Phys. Rev. D 97 (2018) 072003

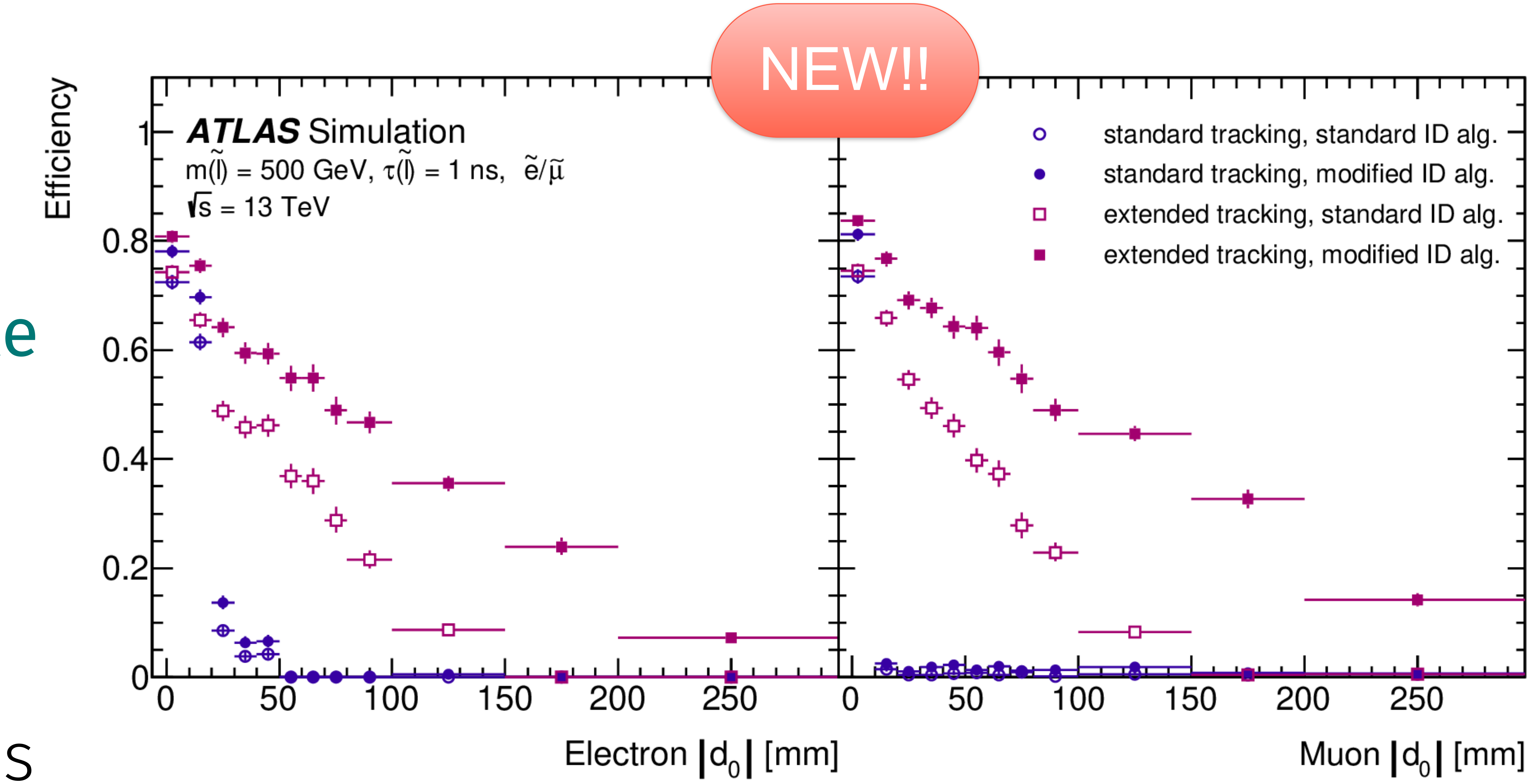


- Prompt lepton identification essential for several analysis (e.g. ttH)
- Non-prompt leptons are rejected using a **BDT**, taking as input the **energy deposits** and charged-particle tracks in a cone around the lepton direction
- Prompt Muon (electron) **Identification efficiency** about 70% (60%) for p_T~10 GeV, plateauing at 98% (96%) at p_T ~ 45 GeV for selected WP
- **Rejection factor** against leptons from the decay of b hadrons is about 20
- Scale Factor between 0.9 and 1.0

Displaced lepton reconstruction

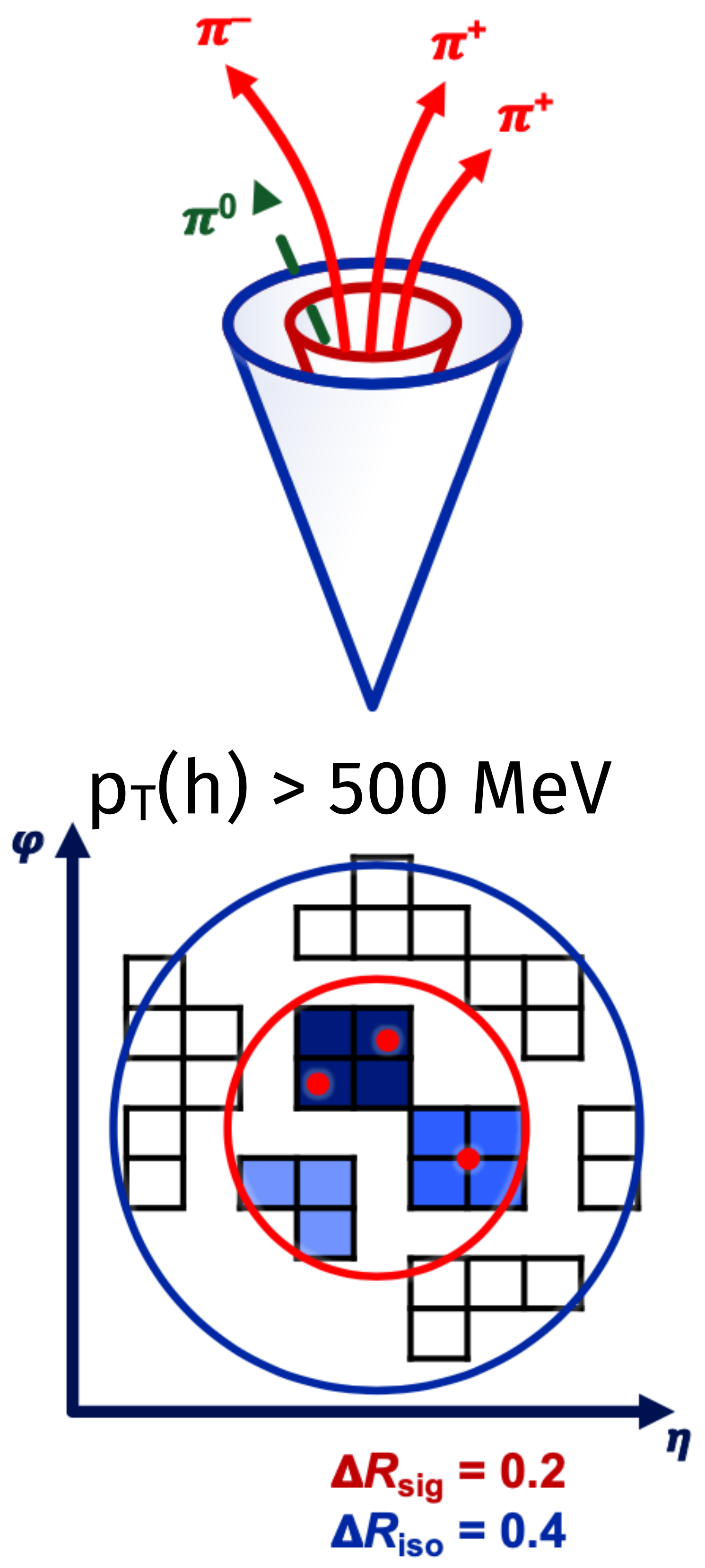
arXiv:2011.07812

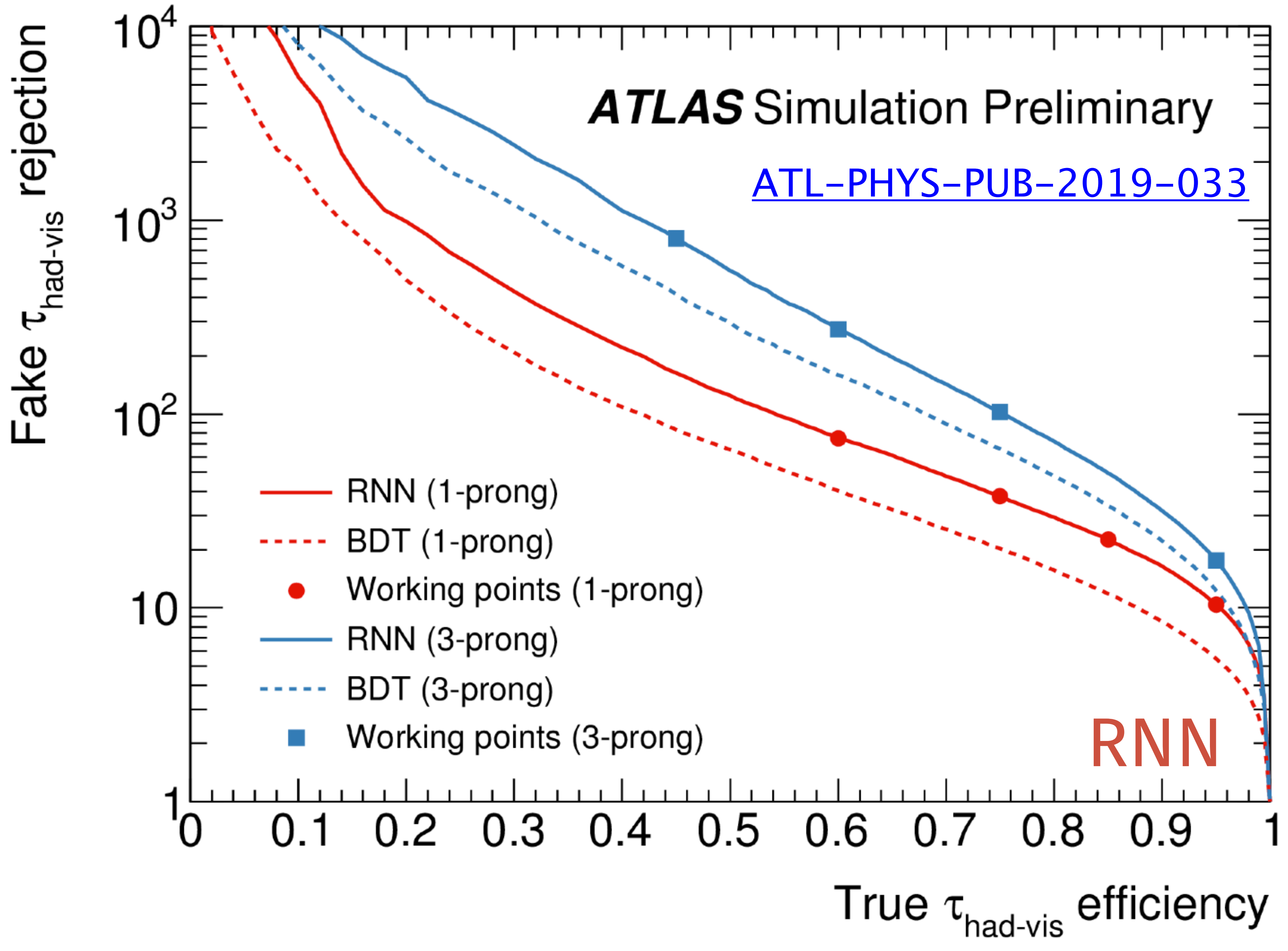
- Displaced lepton reconstruction fundamental to explore several BSM models, e.g. GMSB SUSY
  - Displaced leptons with no visible decay vertex
- Using triggers without tracking information
- Standard tracking: reconstructs tracks with $|d_0|$< 10mm, then adds tracks with $|d_0|$<300mm with remaining hits
- Extended tracking: matching to EM cluster or MS segments



- Modified ID algorithm removes requirements on $|d_0|$ and matched hits
- Clear improvement w.r.t. to standard algorithm

Tau Reconstruction





- Tau seeded from anti-kt4 jets
- BDT track classification
- particle flow: π^0 built from EM clusters subtracting EM energy from charged pions
- BDT to better separate tau decay modes
- Boosted regression tree (BRT) to calibrate tau energy

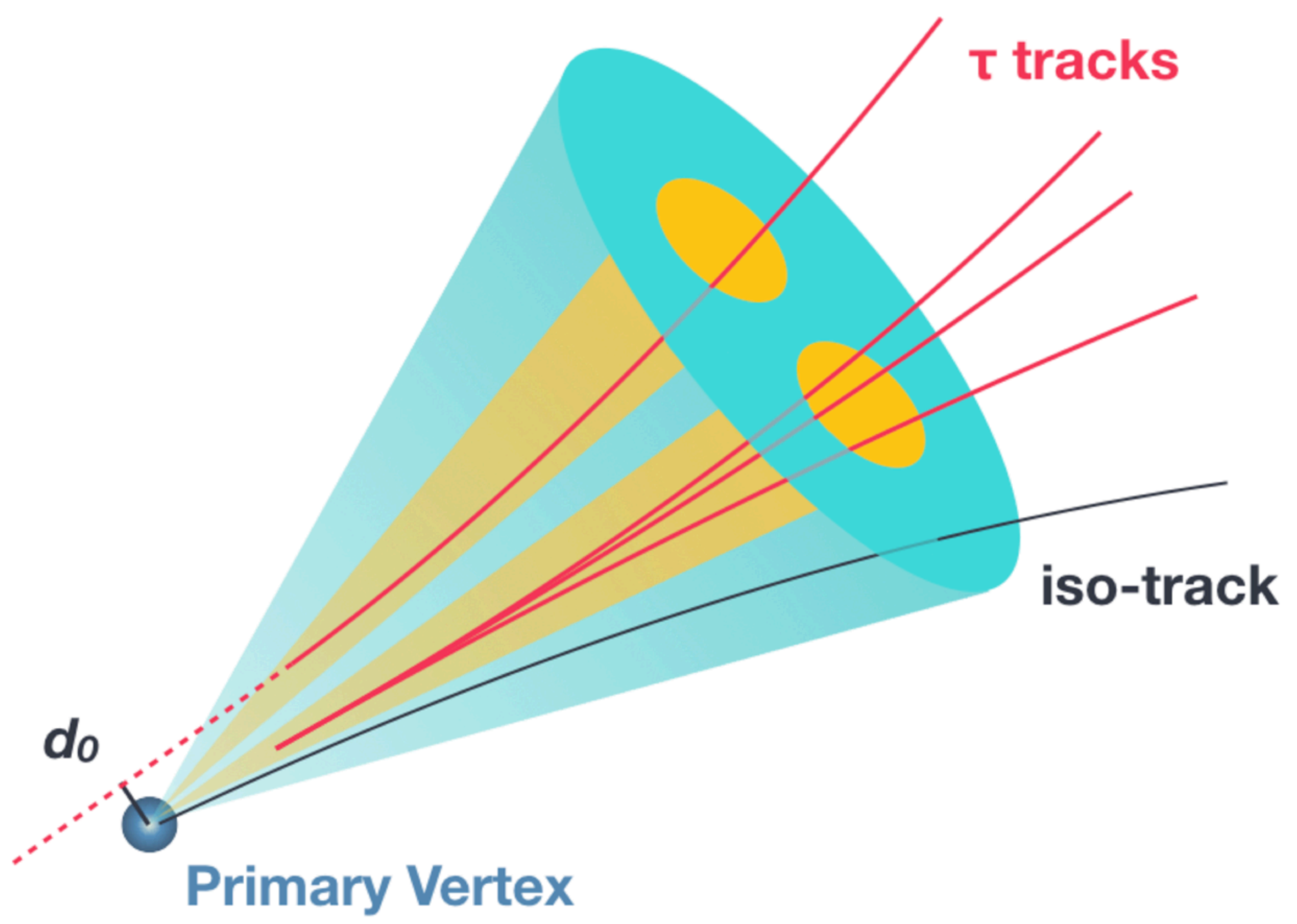
RNN Algorithm

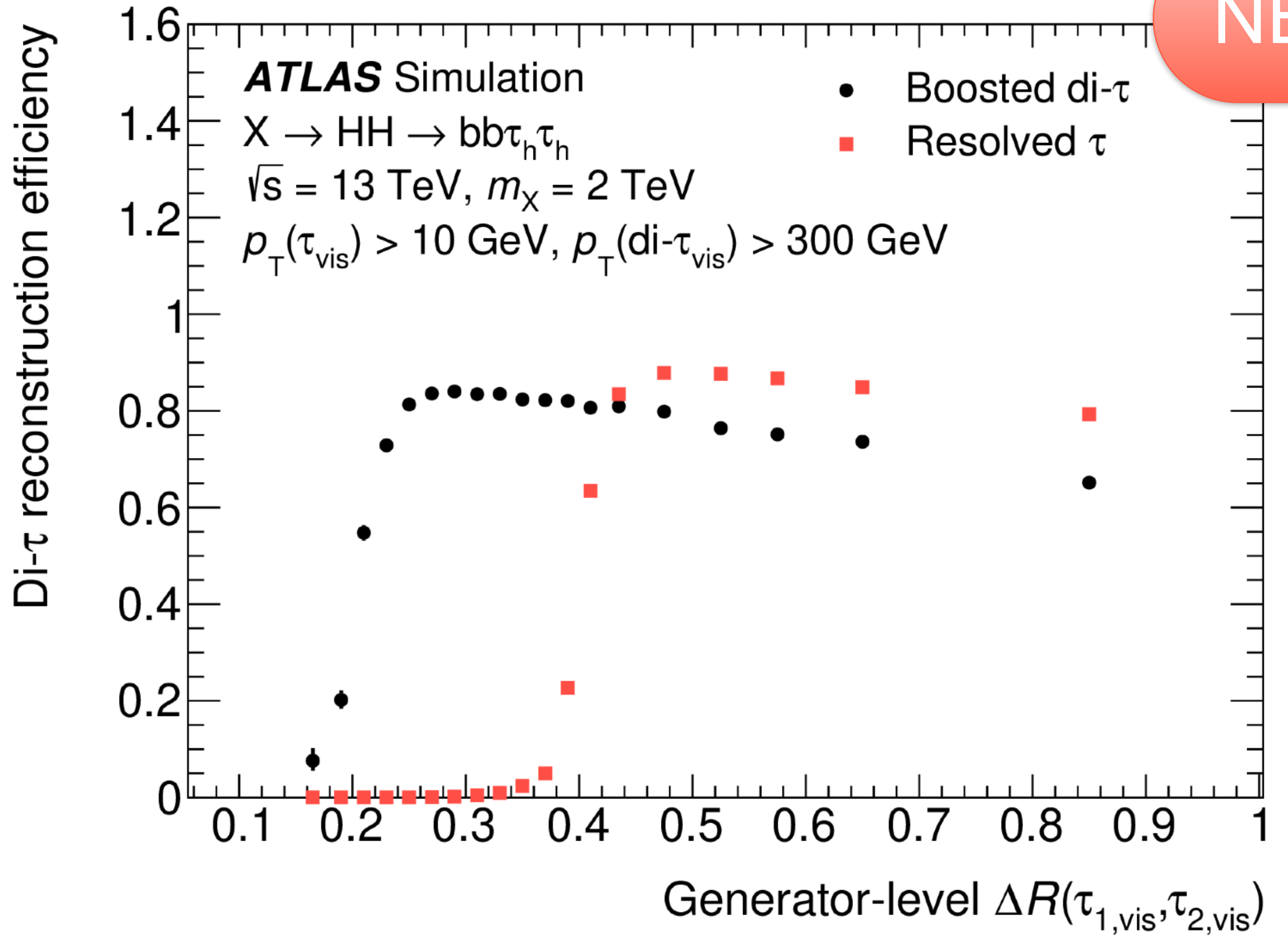
- recurrent neural networks discriminating jets
- input variables related to
  - high-level: τ lifetime, isolation, energy fractions, ...
  - low-level: tracks and clusters

10.1007/JHEP11(2020)163

Boosted di-τ reconstruction and identification

NEW!!





- Boosted di-τ **fail standard reconstruction** procedure because of small ΔR (<0.4)
- Seeding with **untrimmed large-radius jets** (p_T>300 GeV), having at least two sub-jets
- Leading sub-jets construct di-τ system
  - Tracks matched to **sub-jets if ΔR<0.2**
- Clear improvement in efficiency w.r.t. standard resolved τ reconstruction

Conclusions

- ATLAS performance for leptons and photons meet requirements for run II conditions
- Several activities carried own by the performance and analysis groups
  - New low-mass merged-*ee* reconstruction and identification
  - Full run-II muon reconstruction and identification performance
  - Displaced lepton reconstruction
  - Boosted di-tau reconstruction and identification
- Preparation for run-3 ongoing
- For further discussion: https://cern.zoom.us/j/61590132304?pwd=SU9UT1Q5Y1B3RnUzOHNGWXVjRUJTdz09

References

1. Electron and photon performance measurements with the ATLAS detector using the 2015–2017 LHC proton-proton collision data
2. Measurement of the photon identification efficiencies with the ATLAS detector using LHC Run 2 data collected in 2015 and 2016
3. Evidence for Higgs boson decays to a low-mass dilepton system and a photon in pp collisions at $\sqrt{s}$ = 13 TeV with the ATLAS detector
4. Muon reconstruction and identification efficiency in ATLAS using the full Run 2 pp collision data set at $\sqrt{s}$=13 TeV
5. Search for displaced leptons in $\sqrt{s}$=13 TeV pp collisions with the ATLAS detector
6. Reconstruction, Energy Calibration, and Identification of Hadronically Decaying Tau Leptons in the ATLAS Experiment for Run-2 of the LHC
7. Identification of hadronic tau lepton decays using neural networks in the ATLAS experiment
8. Measurement of the tau lepton reconstruction and identification performance in the ATLAS experiment using pp collisions at $\sqrt{s}$=13 TeV
9. Reconstruction and identification of boosted di-τ systems in a search for Higgs boson pairs using 13 TeV proton−proton collision data in ATLAS

Thank you for listening, any questions?

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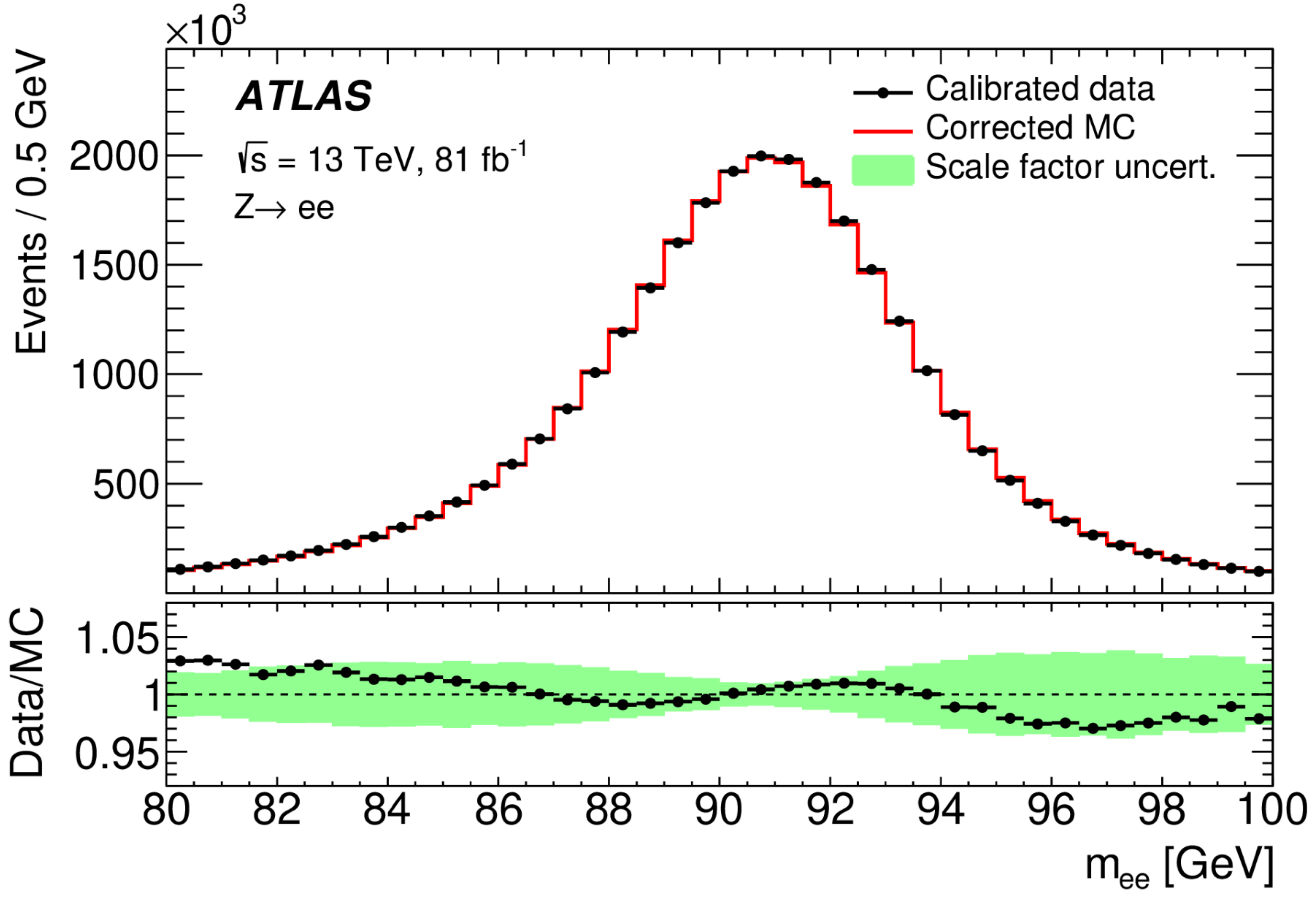
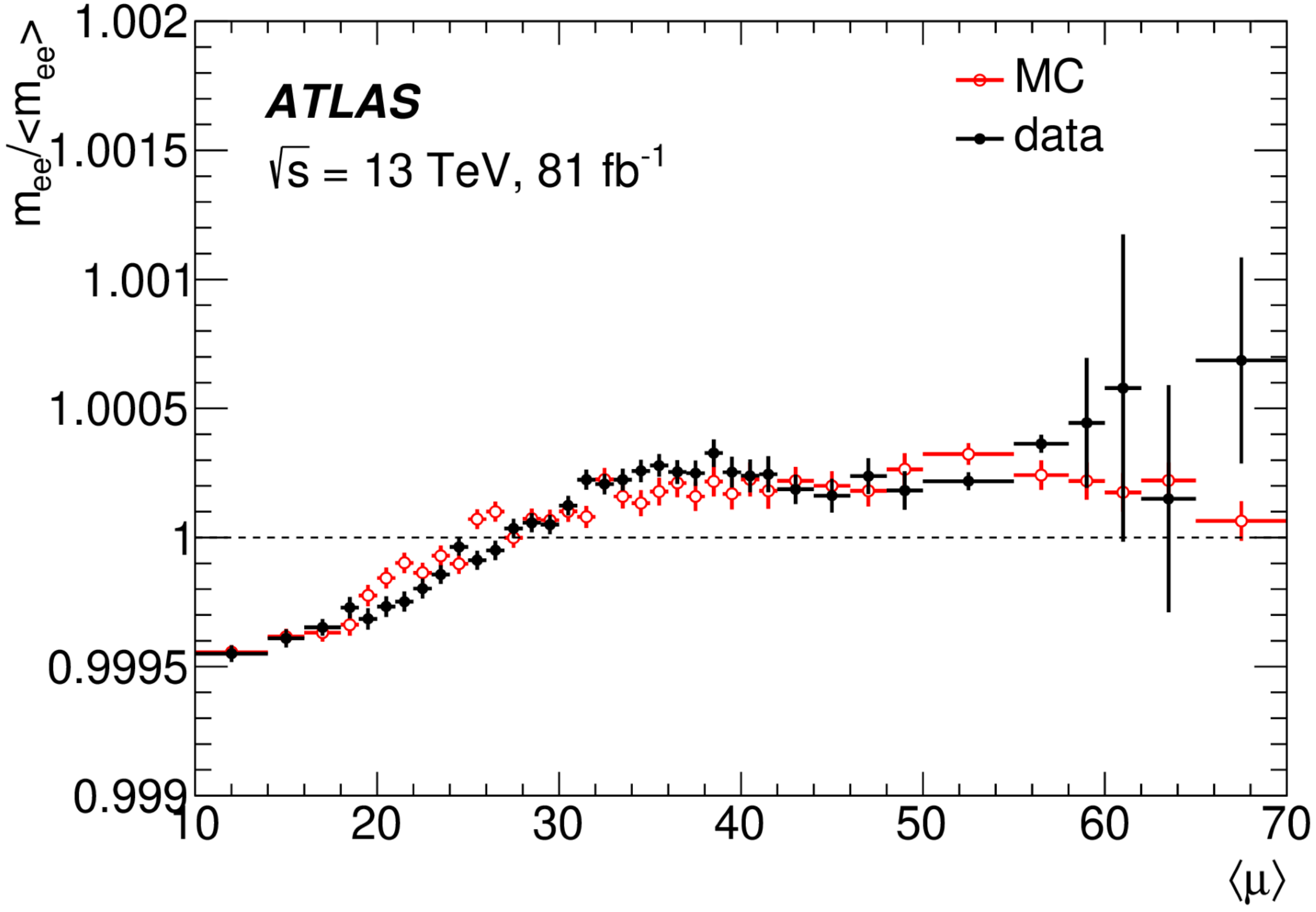
JINST 14 (2019) P12006

Electron and Photon Energy Calibration





- Z->ee events used to calibrate energy scale and resolution
- Scale uncertainties 0.04% to 0.2%

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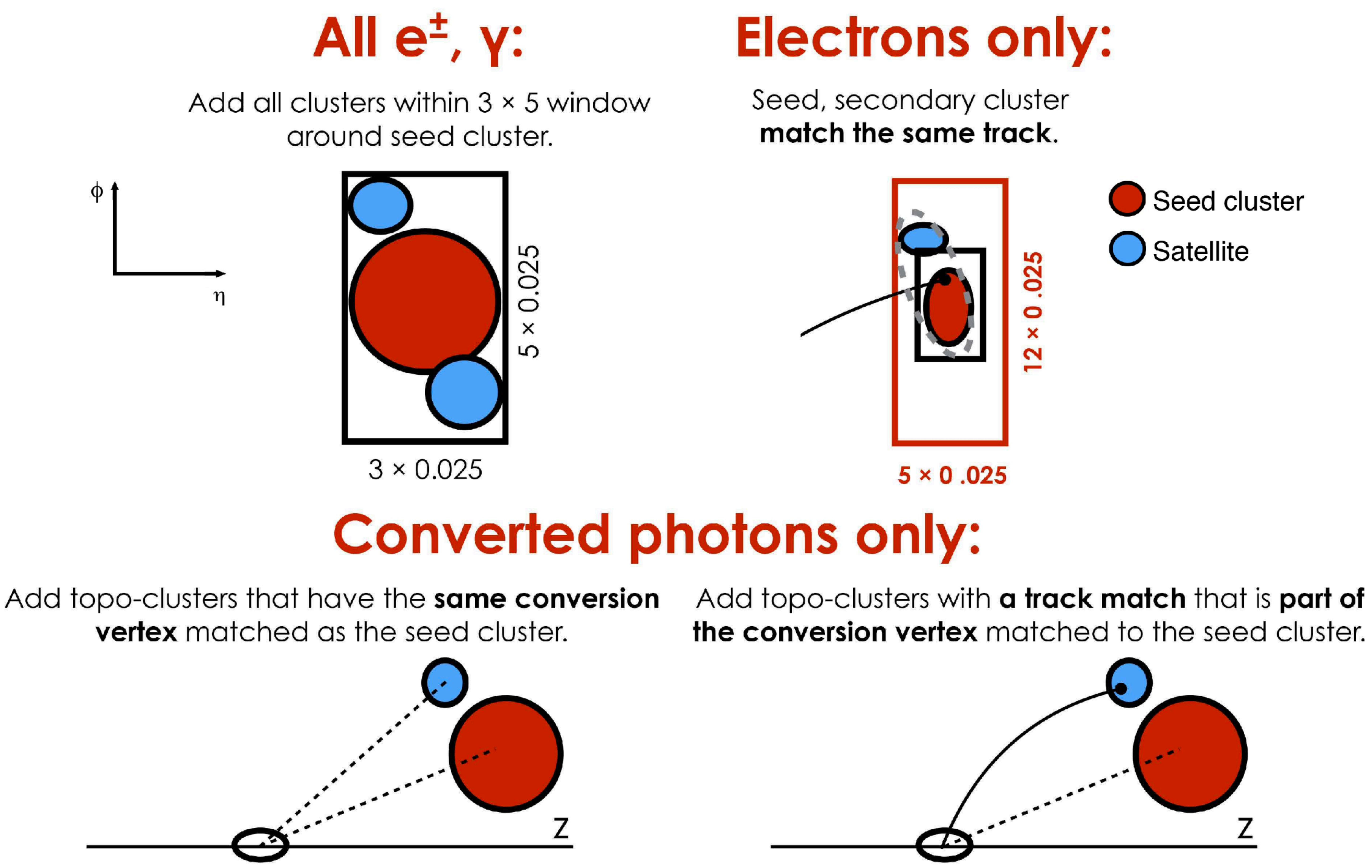
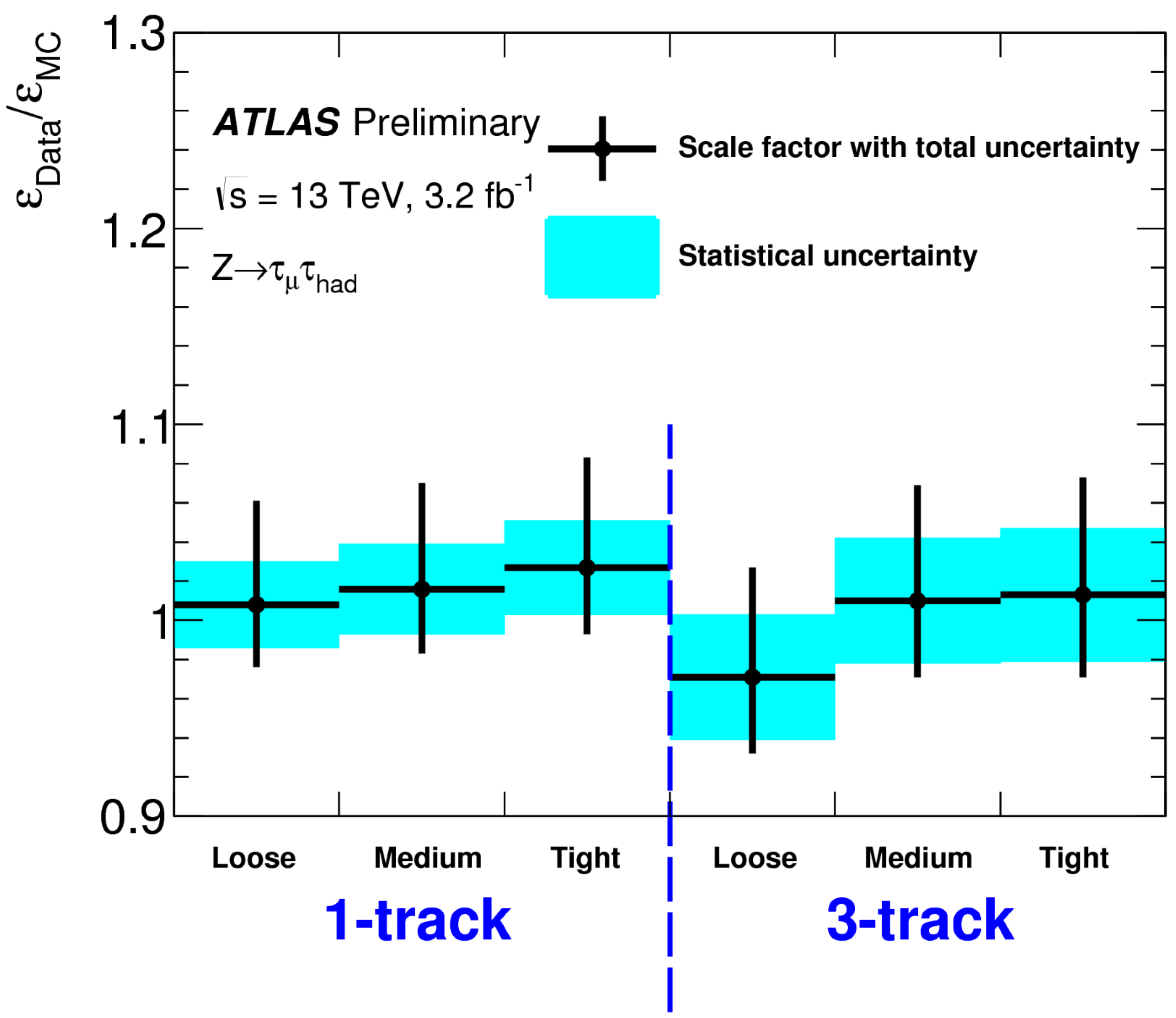
Electron and Photon Superclusters



Tau Identification

ATLAS-CONF-2017-029

- Scale Factors measured with tag and probe method
- Considering Z->$\tau_\mu\tau_{had}$ decays, using τ_μ as tag
- Three Working Points corresponding to different target efficiency values
- SFs around 1 with a max 5% uncertainty



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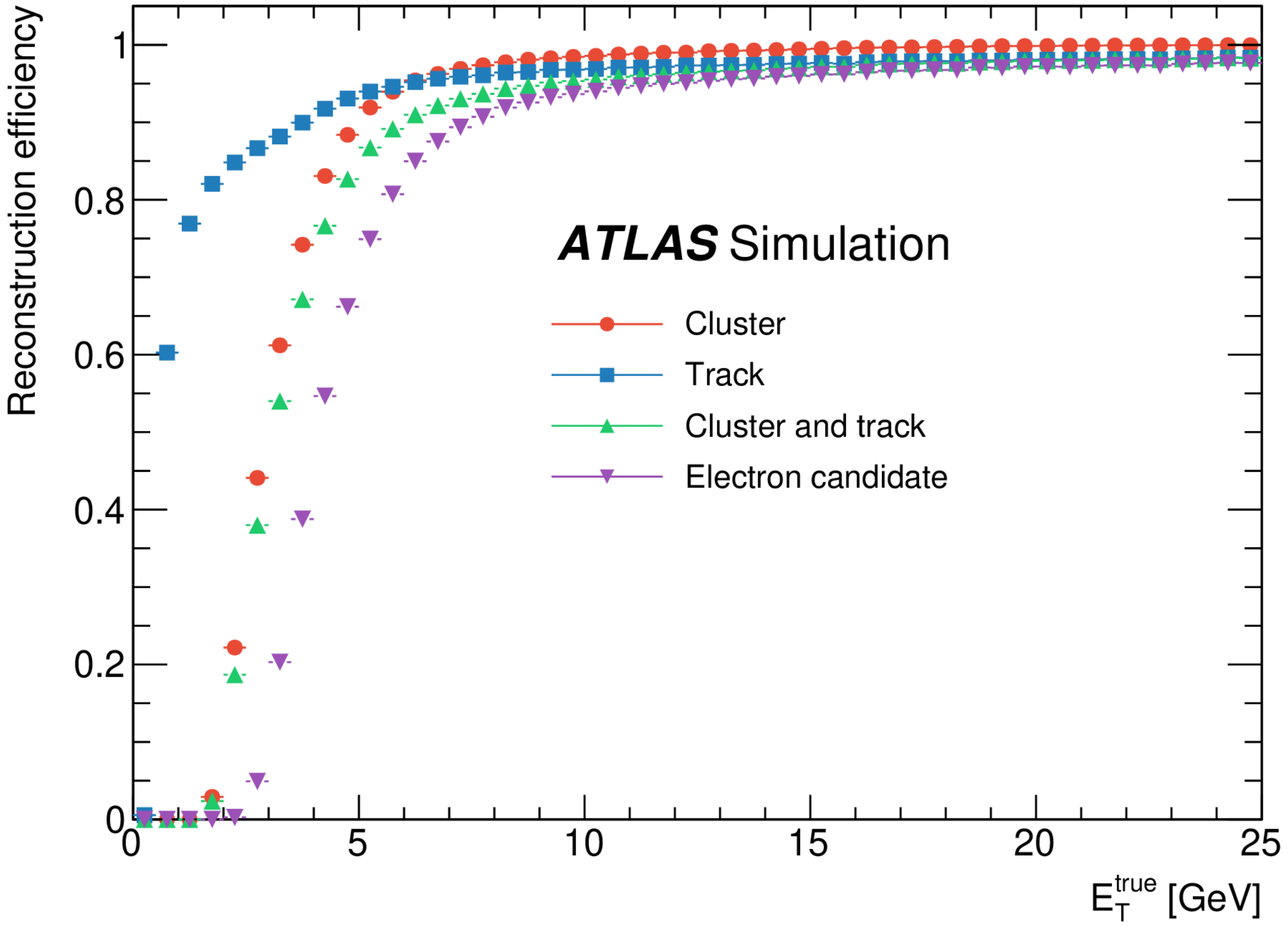
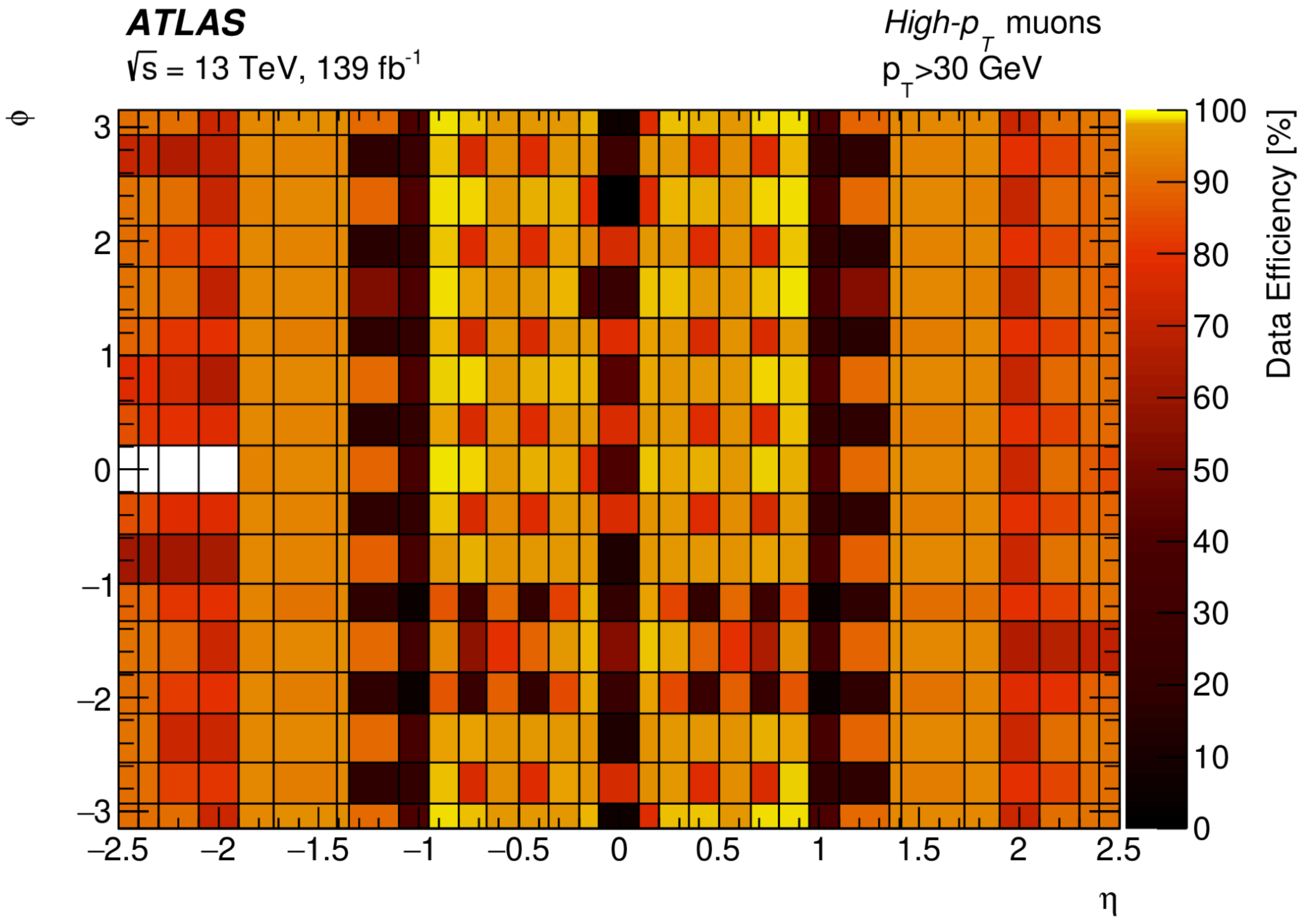
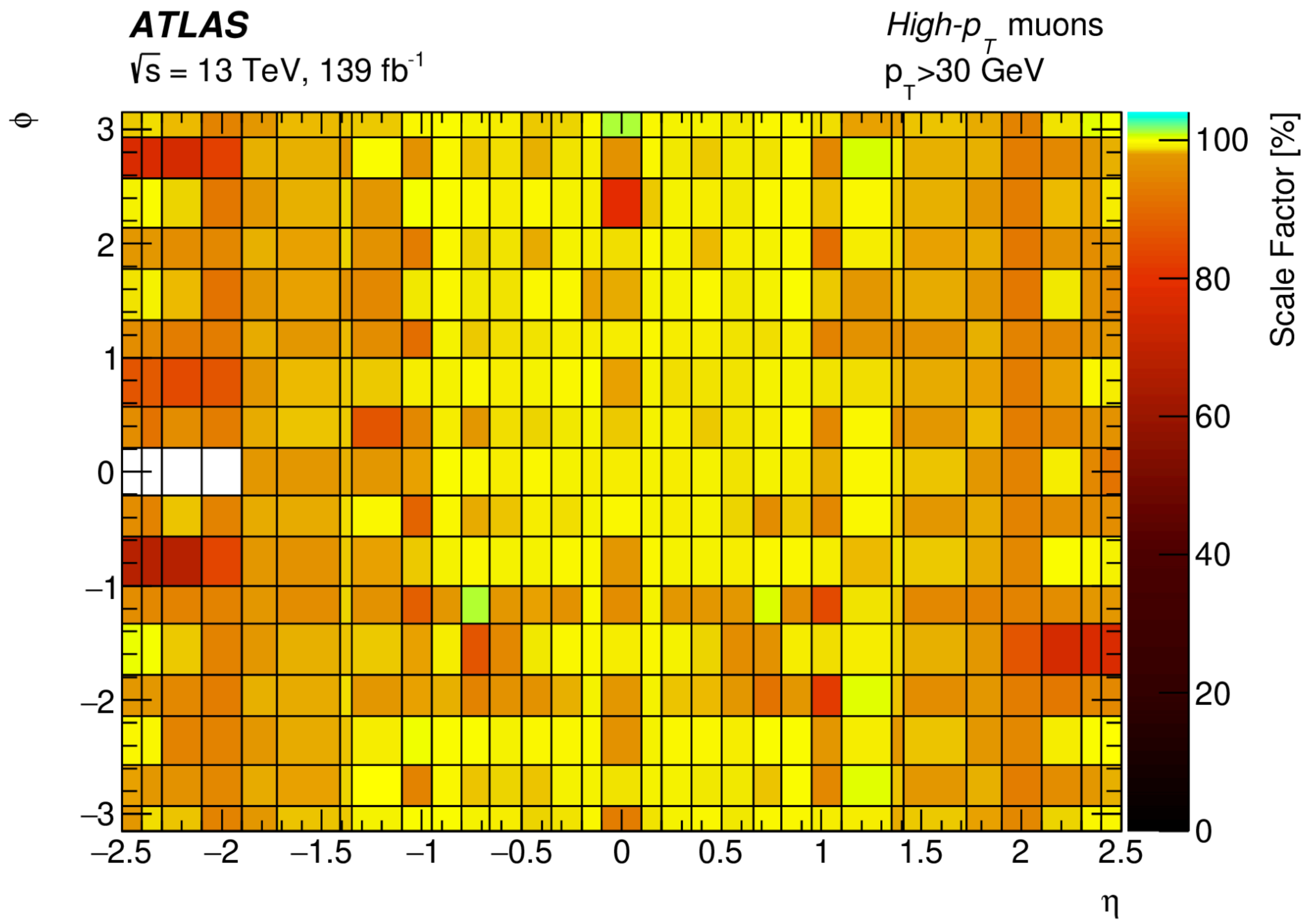
Electron and Photon Reconstruction efficiency



High-pT muon identification

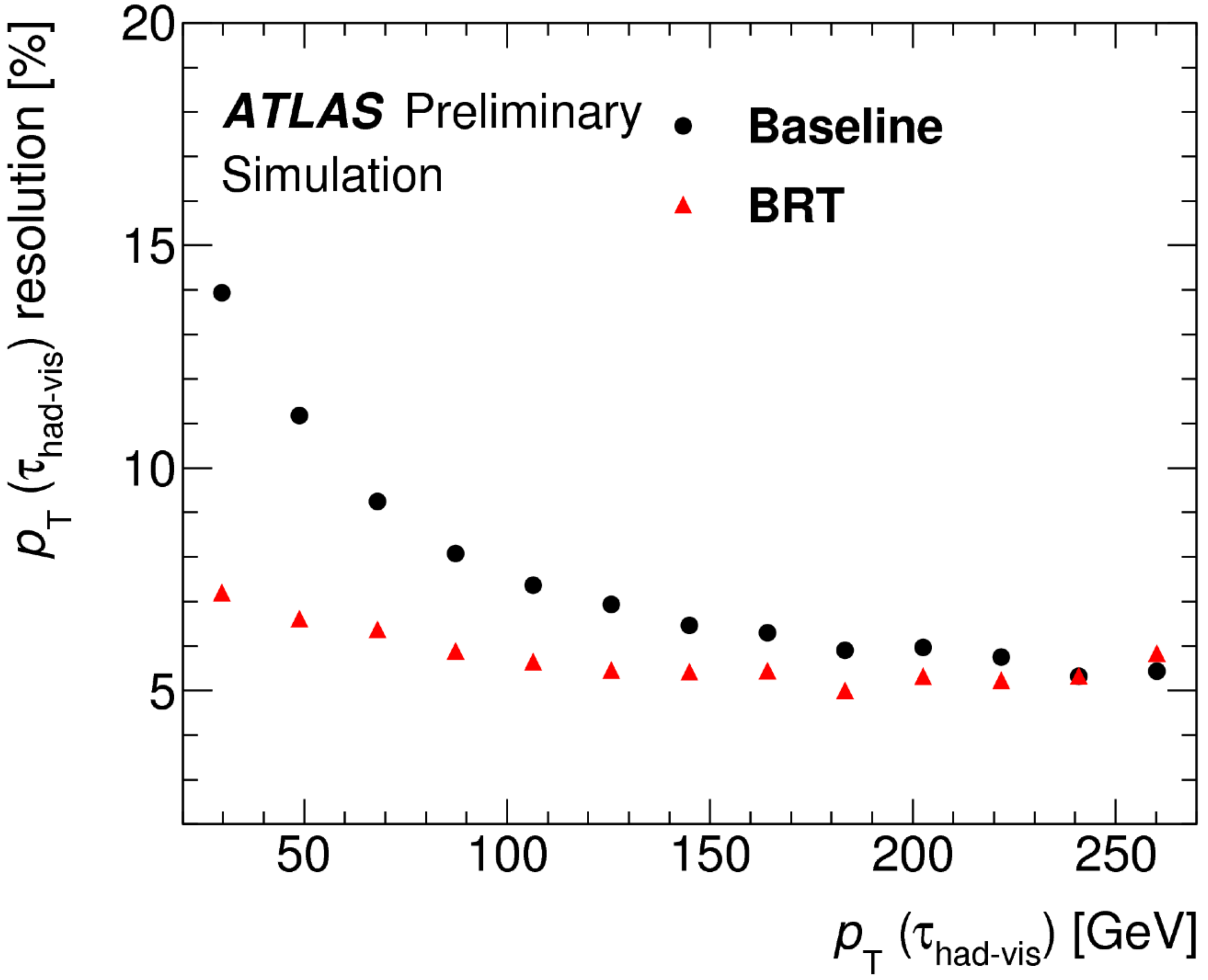
arXiv:2012.00578

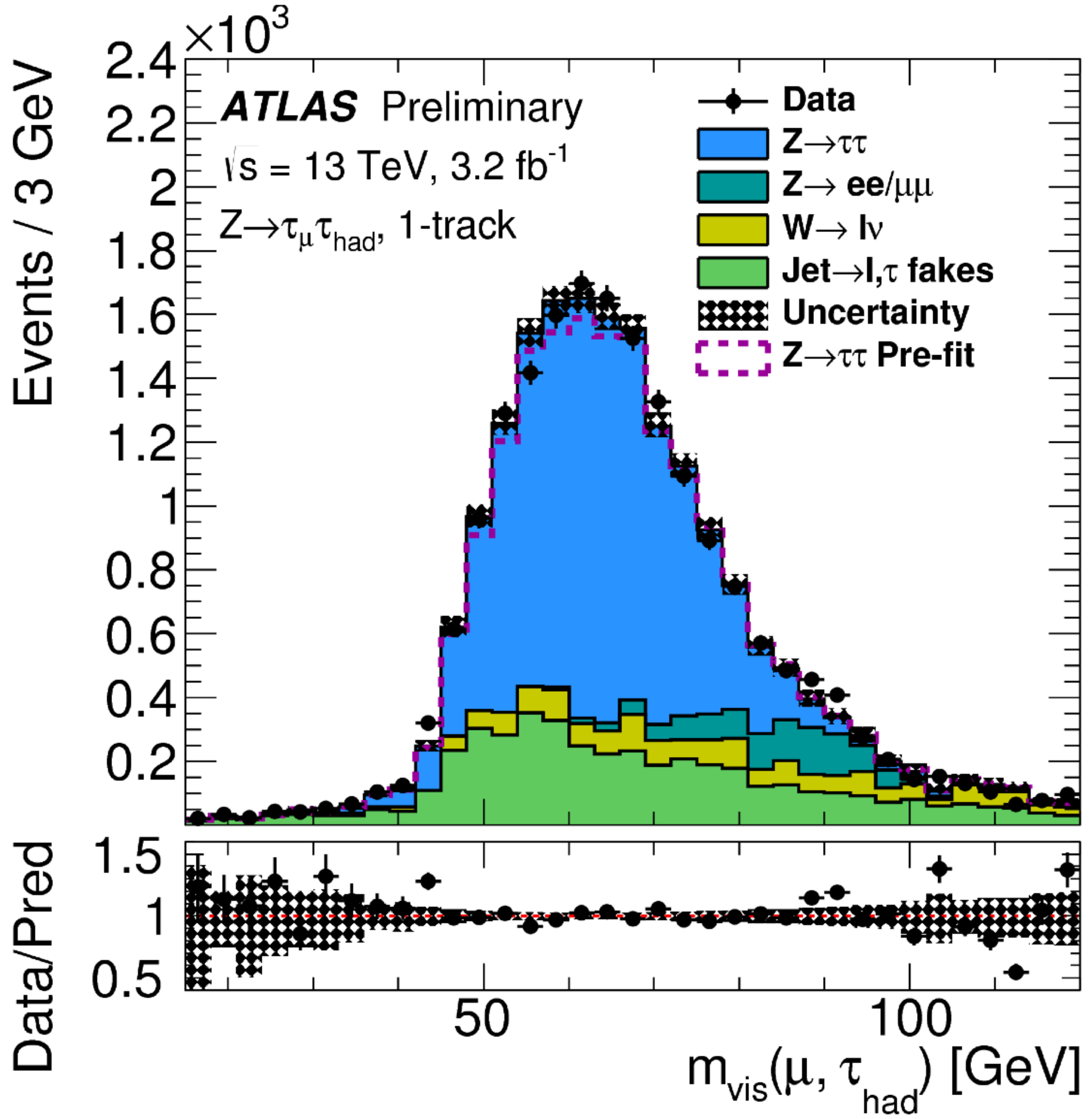




Tau Energy Calibration

ATLAS-CONF-2017-029





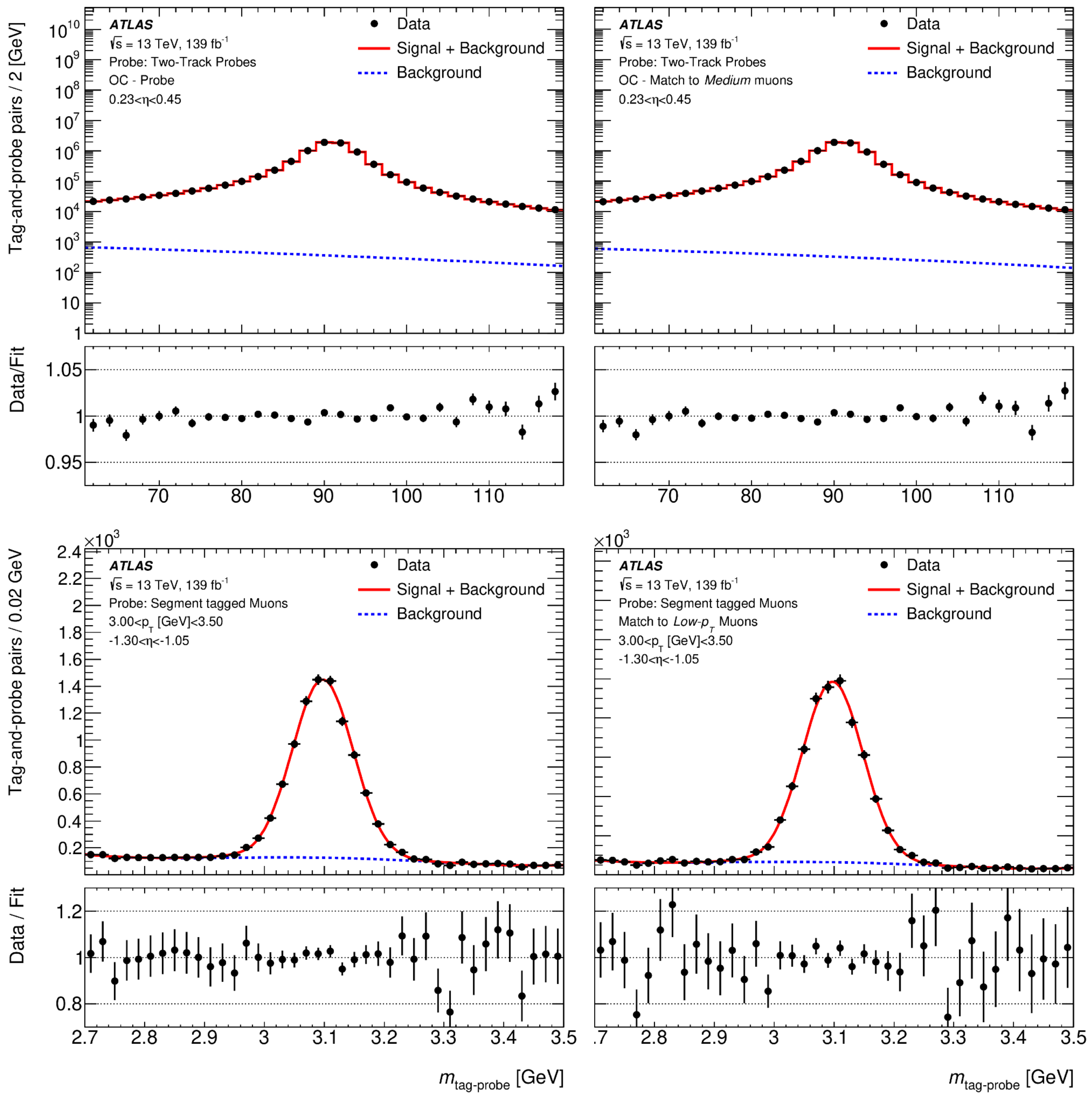
- calibrated for pT(gen) with boosted regression tree (BRT)
  - interpolated, calo & particle-flow pT
  - calorimeter-related variables N_{PV}, N_{track}, $N_{\pi 0}$,…
- resolution ~6%
- energy scale in MC ~1-3%

Tag & Probe Method

- Considering sample with dimuon pairs (Z or J/ψ)
- *Tag* muon required stringent identification criteria and triggers the event selection
- *Probe* used to test efficiency of a particular WP X

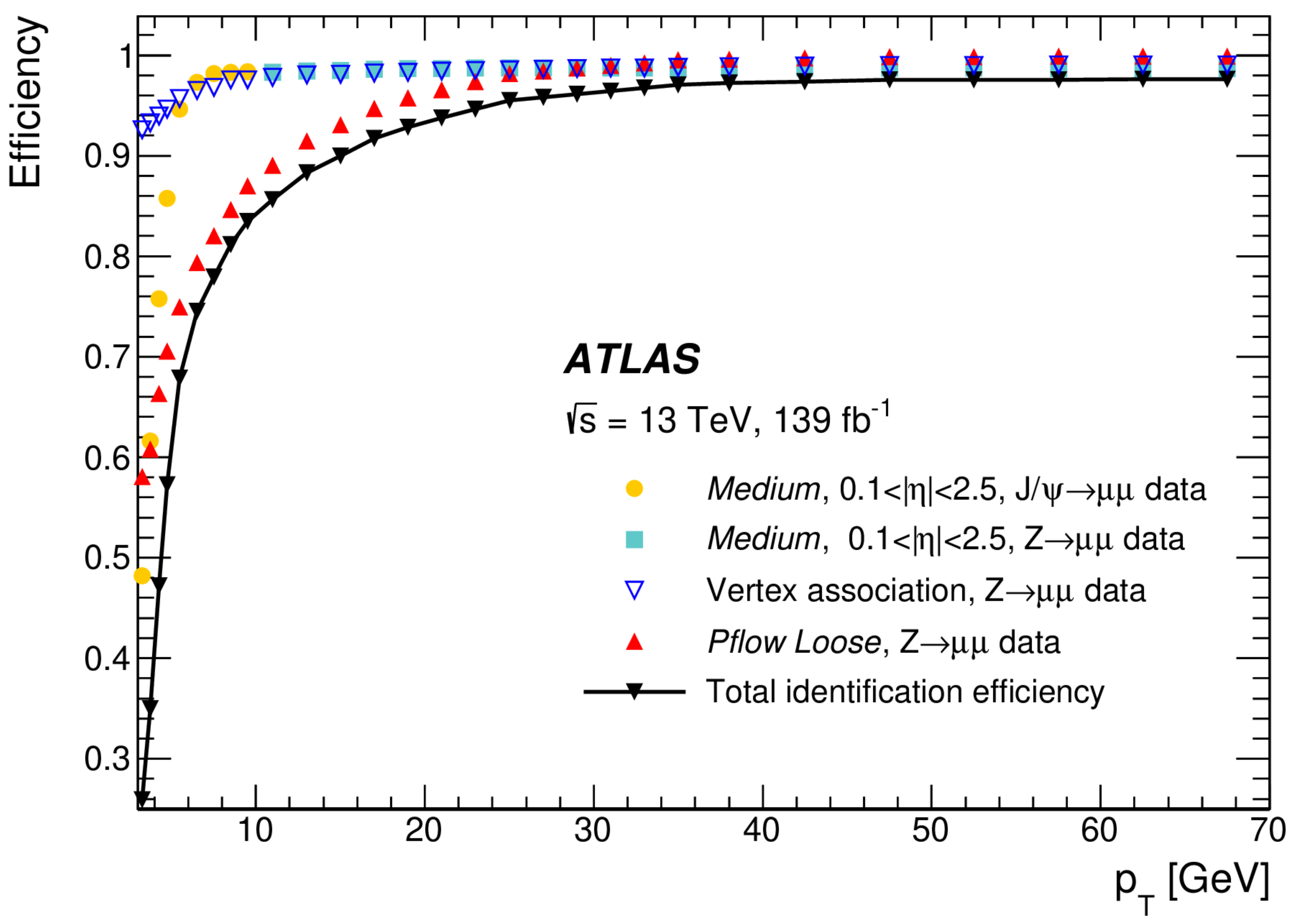
$$\epsilon(X|P) = \frac{N^{X}_{\text{Probe}}}{N^{\text{All}}_{\text{Probe}}}$$

arXiv:2012.00578



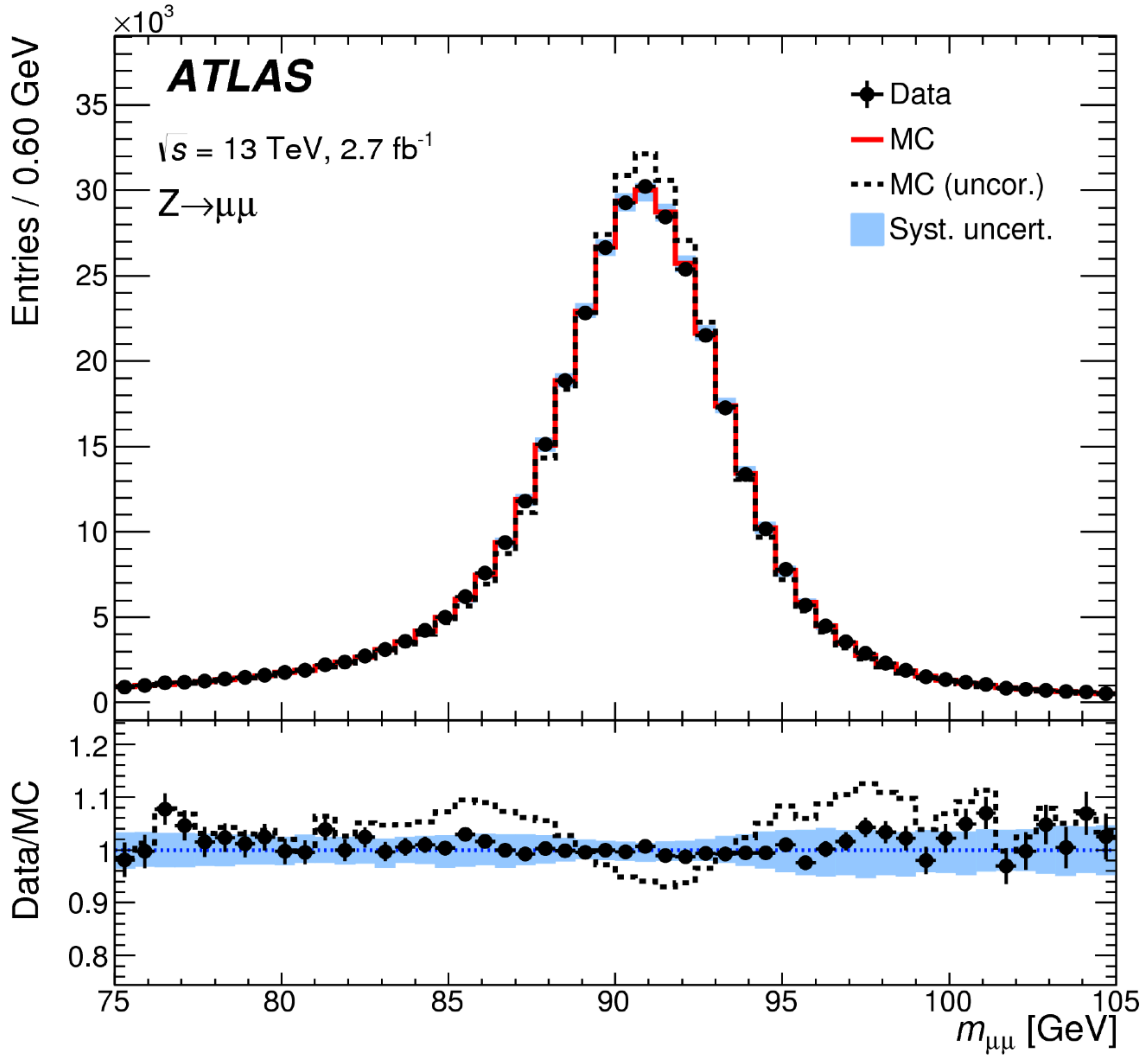
Muon Total Identification Efficiency

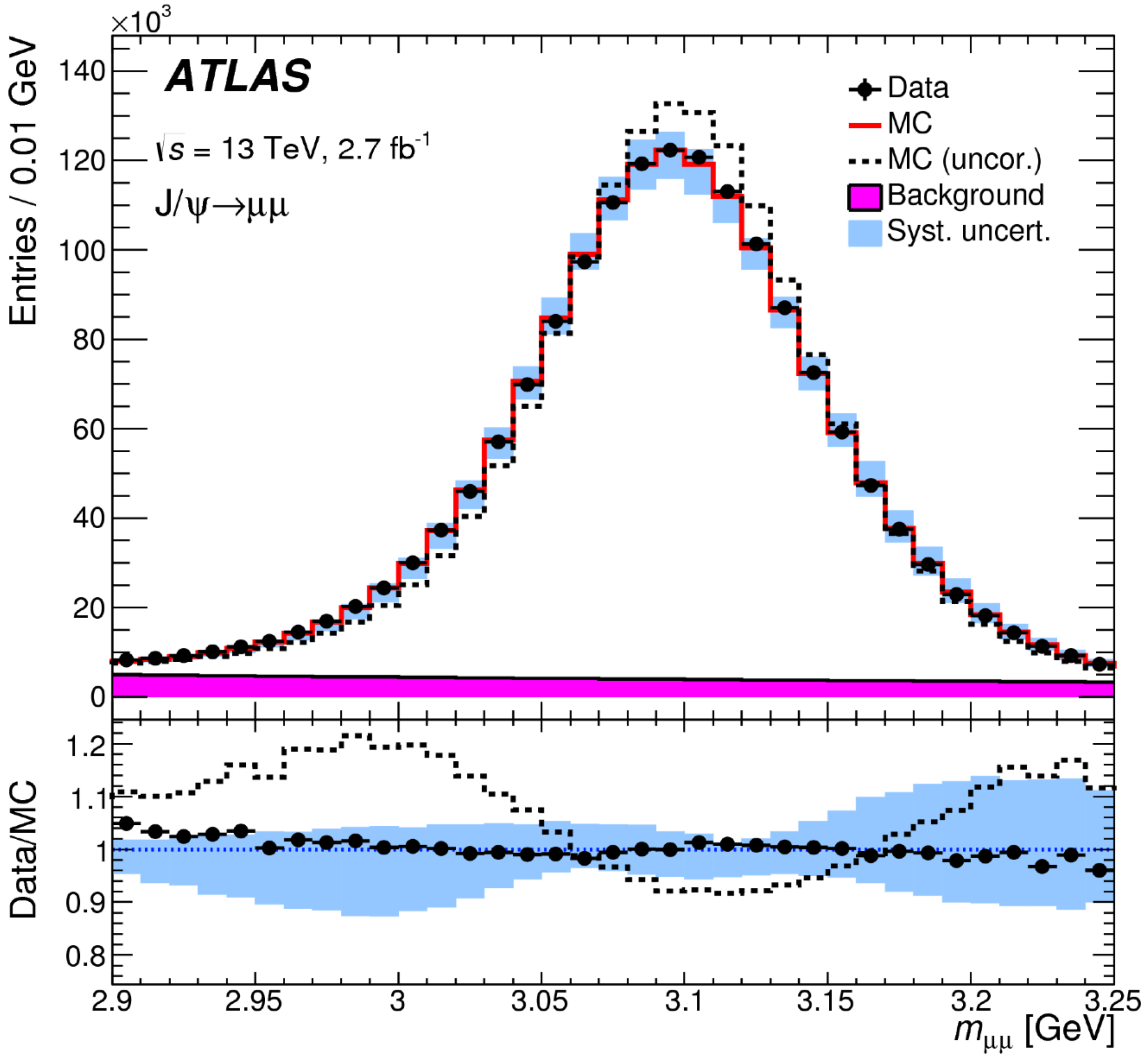
- Overall reconstruction and identification efficiency measured in data with $Z \to \mu\mu$ and $J/\psi \to \mu\mu$ decays for prompt muons with pT > 3 GeV
- The total identification efficiency for satisfying simultaneously the Medium, PflowLoose isolation and vertex association criteria (black line) is shown together with its separate components (coloured markers).



Muon Momentum Calibration

Eur. Phys. J. C 76 (2016) 292





- A set of corrections is applied to the simulated muon moment to improve data/MC agreement
- Correction parameters extracted using The $J/\psi \to \mu\mu$ and $Z \to \mu\mu$ candidates with two oppositely charged CB Medium muons
- Improved Data/MC agreement. Uncertainties between 5% (Z) and 20% (J/ψ)

Electron Identification

- Three Working Points (WP) constructed using a **likelihood discriminant selection**
  - Variables include information from electron track, transition radiation in TRT, lateral and longitudinal development of EM shower
  - WPs tuned using *Z—>ee* for p_T > 15 GeV and J/ψ for p_T < 15 GeV
- Uncertainties at ±1% above 30 GeV
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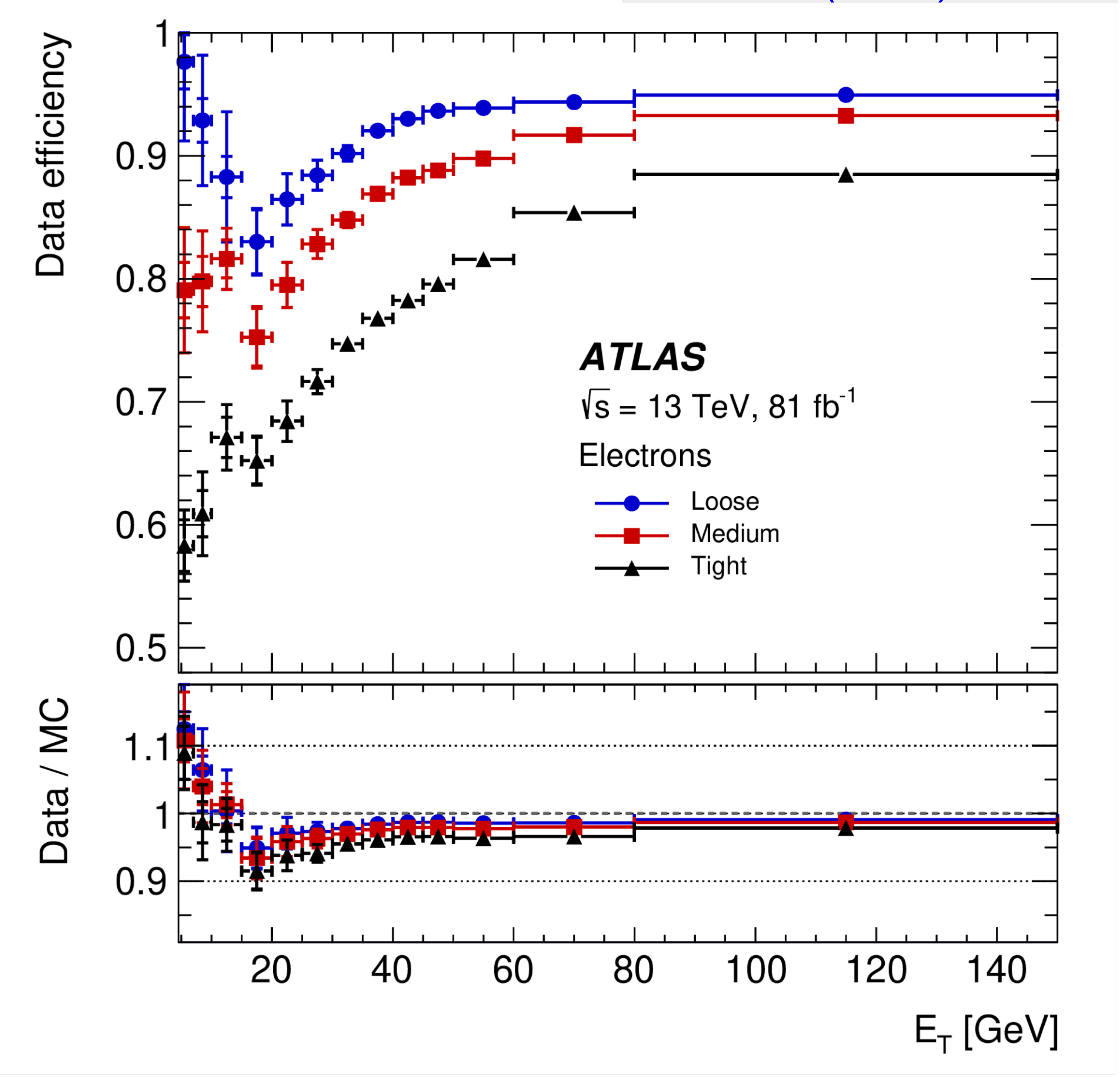

Electron Isolation

- Calorimeter isolation E_T^{Cone} computed using clusters whose barycenters lies within a cone centred around $e\gamma$ cluster
- Track isolation cone size ΔR decreases as function of electron p_T
- Three WPs
- SFs ranges between 1-5% from unity

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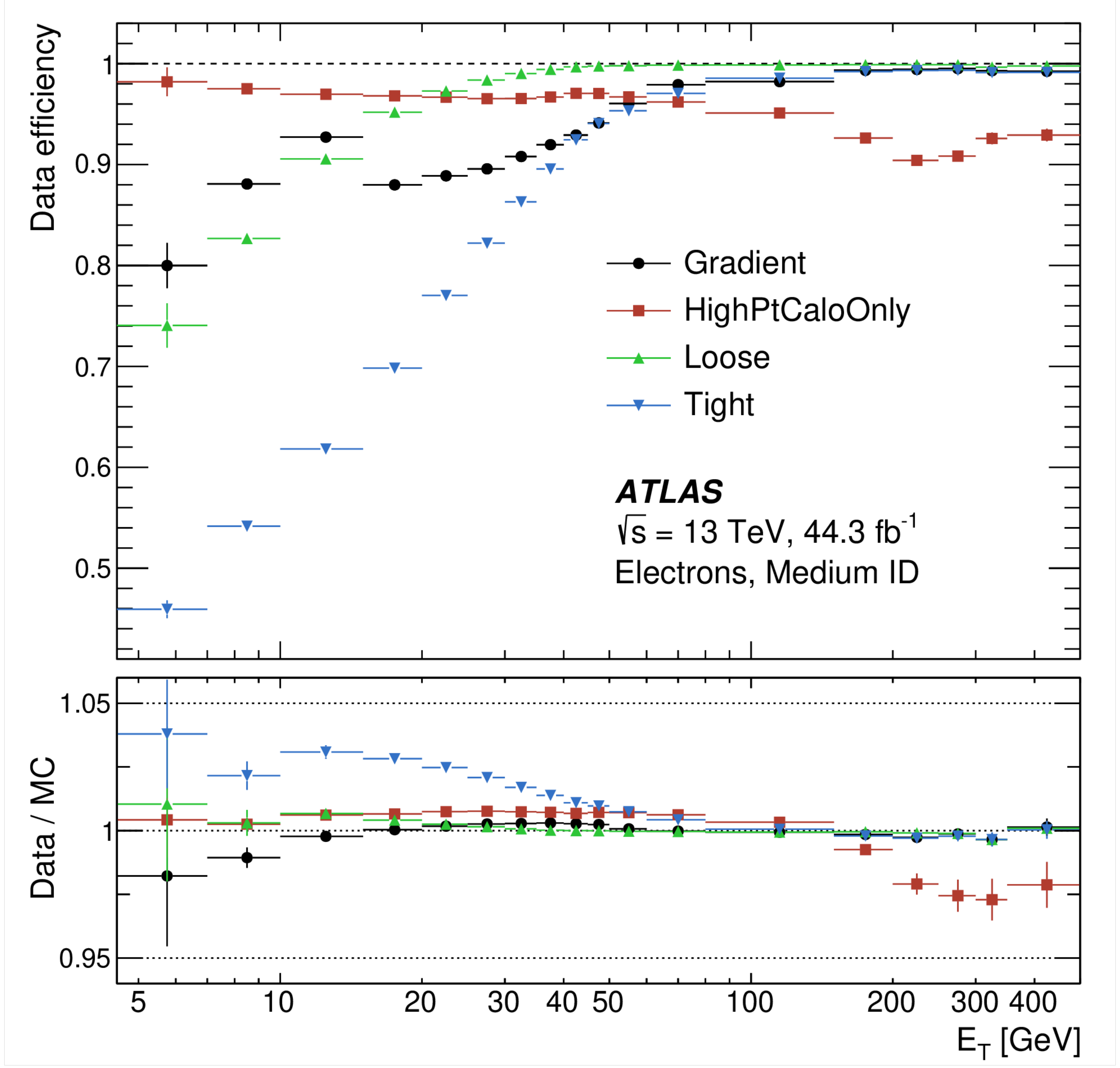

Photon Identification

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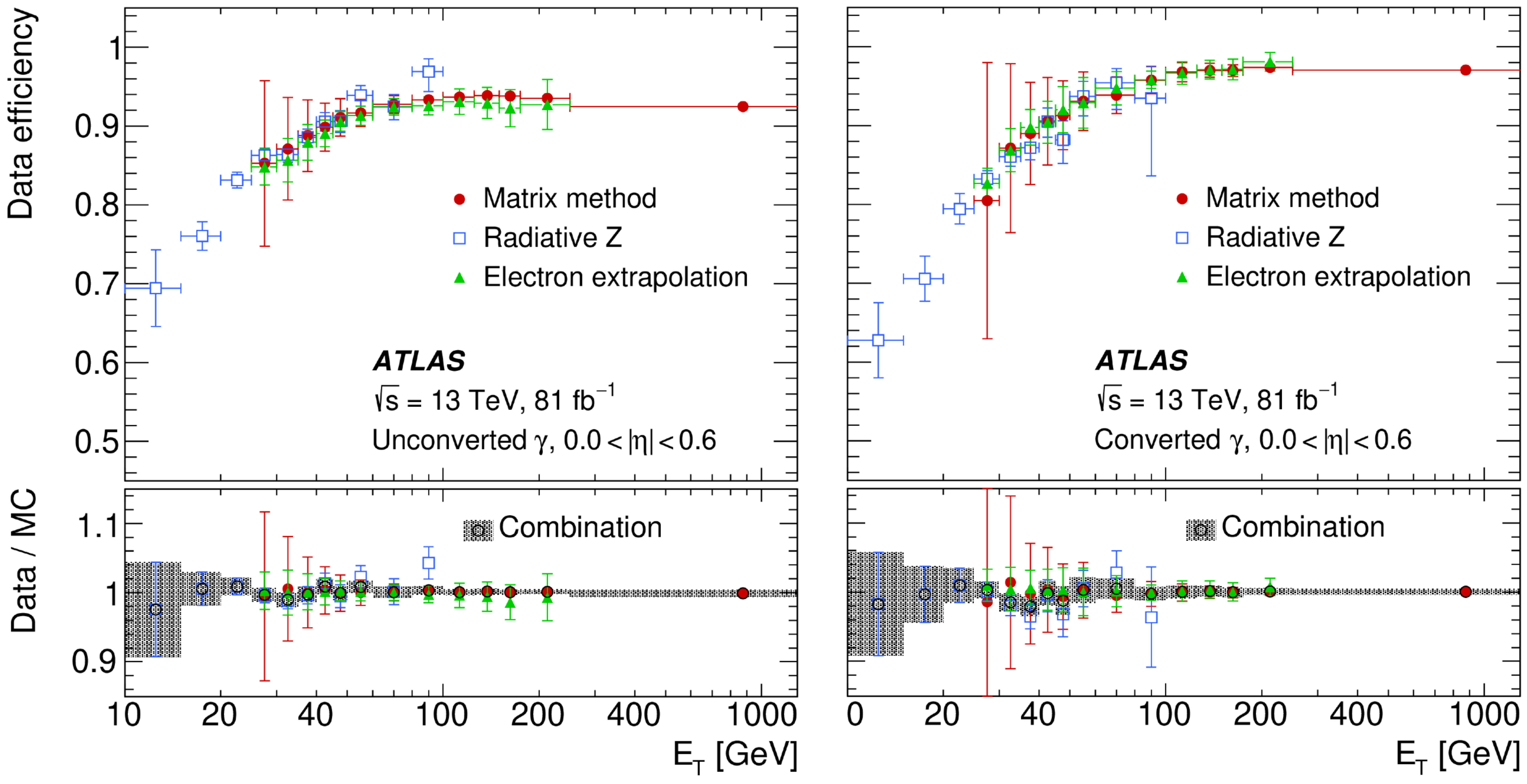

- Photon candidates identified applying cuts on calorimetric variables (**shower shapes, deposited energy in the HCAL**)
- MC shower shapes corrected with data-driven "**fudge**" factor
- Three methods for photon identification efficiency
  - Inclusive photons, *Z->llγ*, *Z->ee* events
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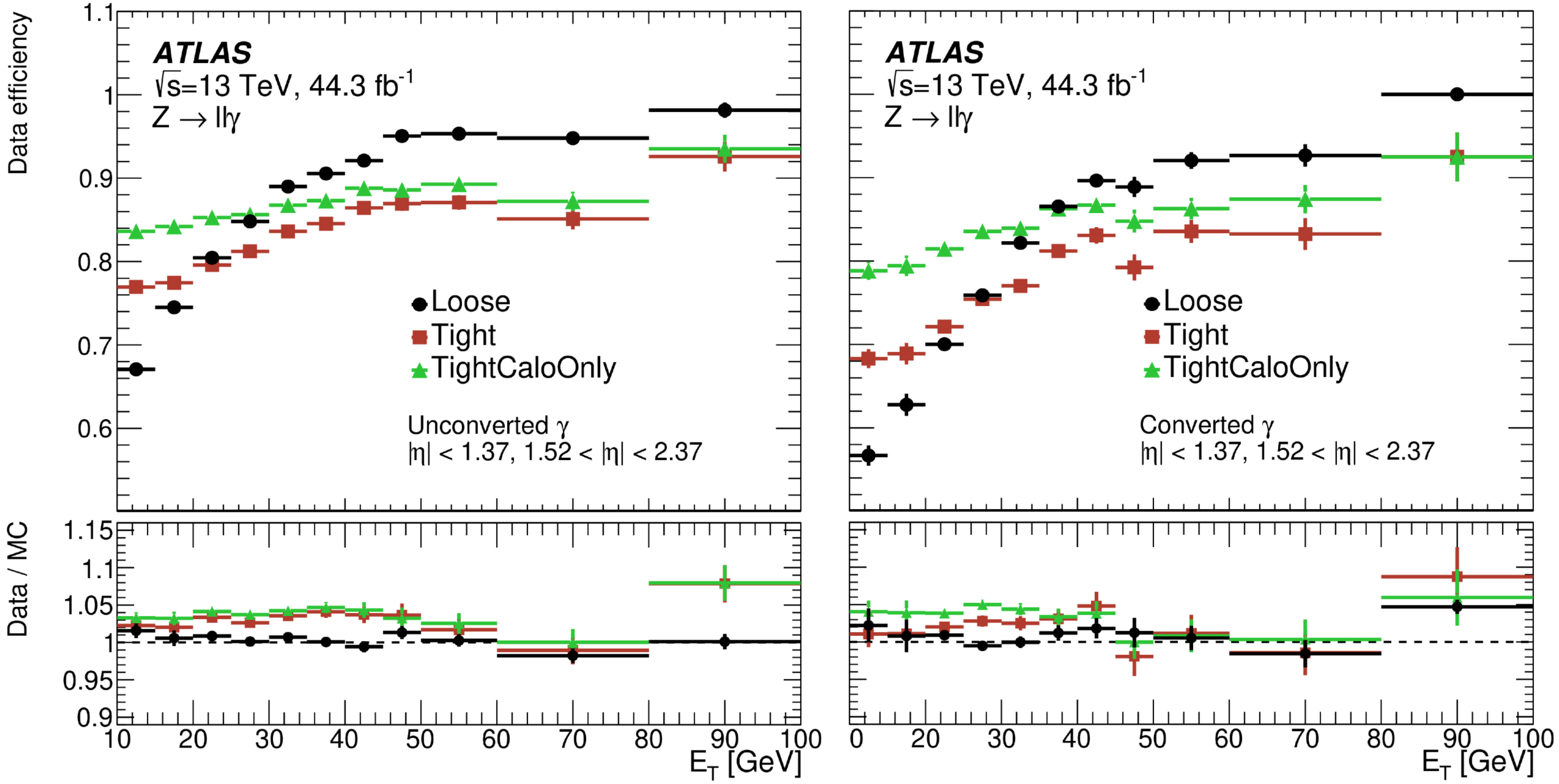
Photon Isolation



- Three WPs with fixed requirements on calorimeter and track isolations
- Measured using *Z—>llγ* radiative decays and inclusive photons
- Overall SFs are within 5% from the unity